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MARINE ATMOSPHERIC BOUNDARY LAYER AND INVERSION FORECAST MODEL.(U)
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THESIS

Marine Atmospheric Boundary Layer
and Inversion Forecast Model

by

DAVID ALMY BROWER

MARCH 1982

Thesis Advisor: K. L. DAVIDSON

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A computer code for prediction of the marine atmospheric boundary layer is developed. The code is used to predict changes of the capping inversion height, the strength of the specific humidity and potential temperature 'jumps' at the inversion, the well-mixed relative humidity in the layer and the lifting condensation level for possible cloud/fog formation. The code is based on recently formulated integrated models for the clear or cloudy marine

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planetary boundary layer capped by an inversion. The initialization is based on radiosonde data and, as such, the code was developed to be used with the Integrated Refractive Effects Prediction System (IREPS) assessment Code. It has been extended to be used with any single platform having atmospheric sensing capabilities, radiosonde or dropsonde. IREPS and hence the MABL prediction code are under consideration for inclusion in Tactical Environmental Support System (TESS).

Marine Atmospheric Boundary Layer and Inversion Forecast Model

by

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Lieutenant, United States Navy

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Submitted in partial fulfillment of the

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A computer code for prediction of the marine atmospheric boundary layer is developed. The code is used to predict changes of the capping inversion height, the strength of the specific humidity and potential temperature 'jumps' at the inversion, the well-mixed relative humidity in the layer and the lifting condensation level for possible cloud/fog formation. The code is based on recently formulated integrated models for the clear or cloudy marine planetary boundary layer capped by an inversion. The initialization is based on radiosonde data and, as such, the code was developed to be used with the Integrated Refractive Effects Prediction System (IREPS) assessment code. It has been extended to be used with any single platform having atmospheric sensing capabilities, radiosonde or dropsonde. IREPS and hence the MABL prediction code are under consideration for inclusion in Tactical Environmental Support System (TESS).

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I. INTRODUCTION

Modern warfare has become critically dependent on the entire electromagnetic spectrum for command and control communications, for weapons guidance, for electronic warfare support and for countermeasures. Tactically essential systems are highly affected by the environment even when conditions are not severe in the historical sense. Enhancement or degradation of the operational performances of EM/EO systems has become a primary concern of task force commanders. As such, the deployment of resources and the modification of tactics based upon environmental factors in EM/EO propagation will, to a very large extent, determine the effectiveness of sensor, weapon and communications systems.

Environmental effects on EO/EM system performance can be grouped in the general categories of refraction (EM), wave front distortion (EO), extinction (EO), and dispersion (EM/EO). Environmental factors contributing to these effects are the vertical gradients of pressure, temperature and humidity for refraction, small scale inhomogenities (turbulence) of the index of refraction for wave front distortion, concentration of water vapor and size distributions of aerosols for extinction and turbulent transport for dispersion. All of these factors are multi-variable in terms of their dependence on the routinely

measured and predicted meteorological variables: pressure, wind, temperature and moisture. The gradient of the index of refraction is the only factor for which the required accuracy exists for direct description by existing or forseen measurement capabilities. Turbulence and aerosol descriptions will have to be obtained by indirect methods due to measurement complexities which preclude measurement on operational ships.

There are requirements to describe all of these factors for the atmospheric region extending from the surface to 0.5-1.5 km above the surface, spanning the Marine Atmospheric Boundary Layer (MABL). The MABL is cooler and more moist than the overlying air and is capped by a layer (inversion), 50-100 meters thick, in which temperature increases and humidity decreases with height. Critical values of the index of refraction gradients leading to anamalous EM propagation can be present within the shallow capping inversion because of the humidity and temperature gradients. The entire affected region (duct) extends below the inversion, and determining its lower boundary is essential. High turbulence can be present in the inversion as well as in the surface layer and this can cause degradation of slant path optical propagation. Turbulence intensities in the inversion are usually one to two orders of magnitude greater than they are immediately below,and are two to three orders of magnitude smaller immediately above

the inversion. Tactically significant degradation of infrared energy is due to water vapor absorption and to scattering by marine aerosols, and is thus usually restricted to moist MABL.

All of the above features depend critically on local detailed vertical structure of the atmosphere. Therefore regional climatologies are not useful for operational predictions, because the significant vertical structures are lost in averaging, and also because most historical measurements do not relate to specific EM/EO requirements. Furthermore, the gradients, and hence, the affected regions cannot be explained on the basis of large scale atmospheric flows since the nature of the gradients are due to dynamic processes which are controlled by near surface as well as by larger scale features.

We believe a 'gap' has existed in past efforts to characterize the tactical environmental conditions. The gap is between two extreme approaches of relating conditions to 1) near surface observations, and 2) to larger scale predicted synoptic patterns. Clearly, to assess the above features, local measurements are desirable. Measurements (radiosondes) are made infrequently and, as time progresses, the initial point measurement becomes less applicable and a predictive scheme is needed. One must consider a transition to climatology, large scale numerical analyses and predictions, or dynamic models based on the initial

soundings which are available at the operational location. Climatology has already been addressed and discounted. Ruggles (1975) has examined the capabilities of large scale numerical procedures at remote facilities and has argued convincingly that they are not sufficient.

Needed are characterizations of coupled local oceanic and atmospheric mixed layer features for time scales from 12 to 18 hours and for spatial scales from 50 to 300 km. Significant changes occur in both mixed layers over these temporal and spatial scales. Predicting these changes is now possible using available measurements and reasonable physical models which have recently been formulated.

This paper will describe results from observational and model evaluation/formulation efforts with these models which provide evidence that tactically relevant forecasts can be made over the required scales. The MABL is emphasized in this discussion but, as will be seen, the MABL model must eventually be coupled with an Ocean Boundary Layer (OBL) model to adequately describe the system. This is the object of separate investigation by the author and faculty at NPS.

The long term objective of work in these areas is to make reliable 6-18 hour forecasts of properties within the MABL and OBL. The near term objectives are 1) to verify and reformulate existing models for the responsible physical processes and 2) to develop measurement procedures which are suitable for routine observations from a single ship or

aircraft. For the finalized model it will be necessary to predict such properties as the height of the inversion, the strength of the gradients and fluxes at the inversion and at the surface, and the values of well mixed parameters in the region between the surface and the inversion.

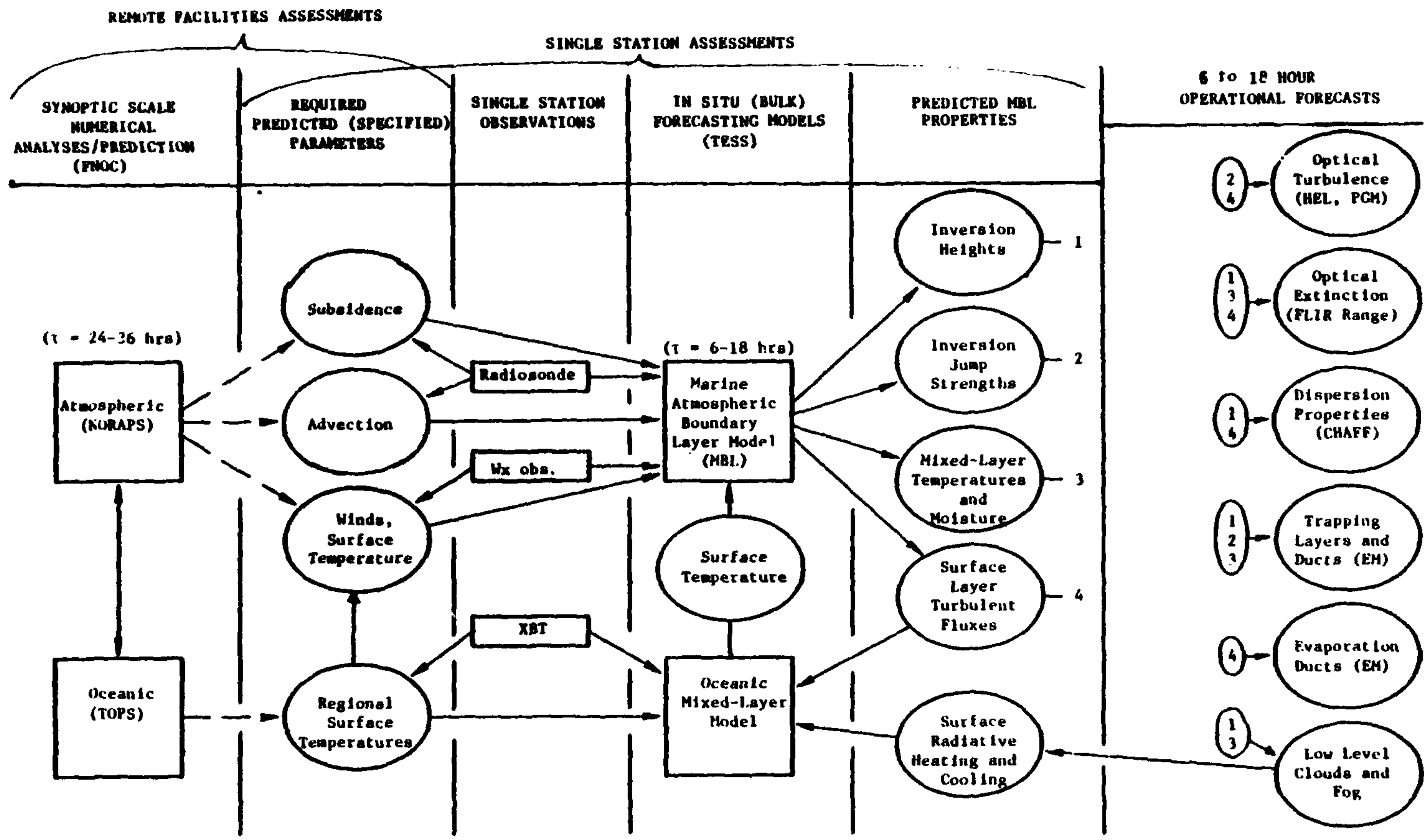


Fig. 1.

Illustration of input parameters, predicted properties and operational forecasts associated with a bulk atmospheric boundary-layer model (MABL). Numbers to the left of operational forecast items pertain to the required predicted MABL properties. The bulk atmosphere and ocean mixed-layer models would be coupled in a shipboard, aircraft micro-computer. Dashed lines (- -) coming from remote facilities imply that the required information could be obtained from these, but the in situ capabilities should be possible without the sources.

II. BACKGROUND

This section will provide a general outline of the environmental descriptions required and the models which can used to predict them. The possible input parameters and models are delineated in Figure 1. Tactical forecasts to which the improved understandings would apply appear on the extreme right hand side. Single station assessment constraints associated with the local atmospheric and ocean models are timely and compatible with the concept of the Tactical Environment Support System (TESS) as recently described by NEPRF scientific personnel (NEPRF METRO Report, July 1981).

As stated, we will consider only the local atmospheric mixed layer model and associated descriptions. The local oceanic predictions would be made by an oceanic mixed-layer model (e.g. Garwood, 1977) and the regional predictions would be made by a three dimensional atmospheric (e.g. NORAPS) and a regional oceanic (e.g. Tactical Ocean Prediction System-TOPS) numerical prediction model. The ocean mixed layer model and the regional numerical prediction schemes are objectives of other basic and exploratory Navy sponsored research efforts.

A. METEOROLOGICAL DESCRIPTIONS AND MODELS

From a local perspective, let us consider an idealization of the oceanic-atmospheric system. The sea-air

interface is bordered by oceanic and atmospheric turbulent mixed layers which effectively insulate the bulk ocean and atmospheric regions. The primary sources of the turbulence within the layers are the velocity (current) and buoyancy (density) gradients at the interface. Even under conditions where the water is slightly cooler than the air, buoyancy forced velocity fluctuations within the layer can be quite large and mix the entire MABL from the surface to the inversion. The large vertical mixing yields constant (well-mixed) wind, temperature and humidity profiles above the surface. At the top of the atmospheric mixed layer there is the inversion, a thin transition region. Examples of observed well-mixed profiles and the inversion are shown in Figure 2(a).

The atmospheric mixed layer interacts with the free atmosphere at this interface by means of turbulence forced entrainment. Entrainment brings dry, warm air into the mixed layer and also increases the surface winds if there are higher winds aloft. Stratus clouds form within the layer if entrainment causes the moist mixed layer to extend above the lifting condensation level.

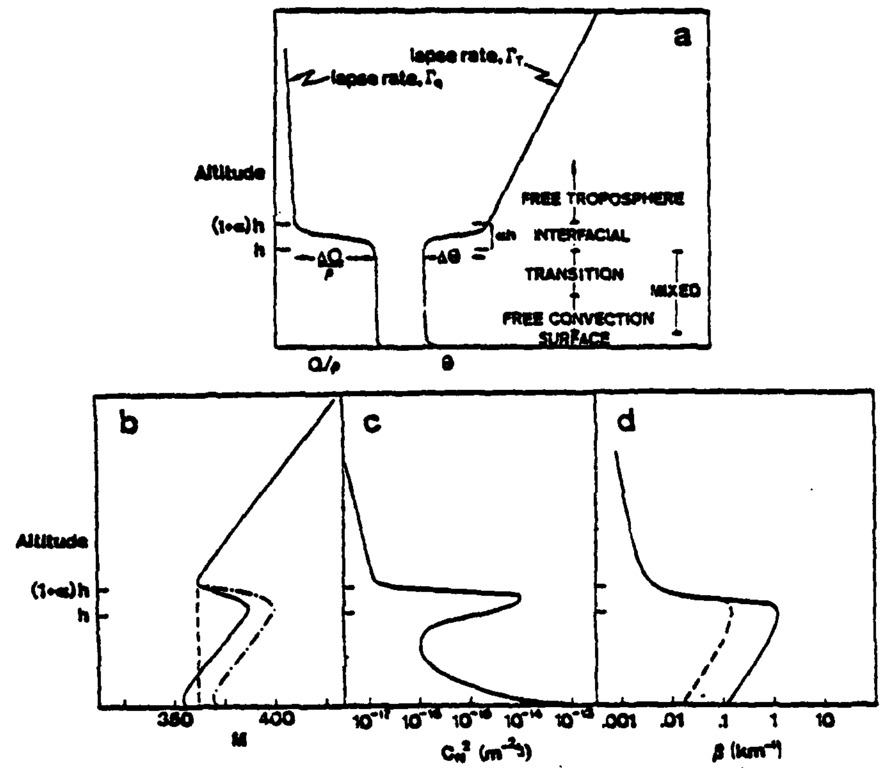


Fig. 2. Simplified meteorological and tactical features of the MABL and overlying region including (a) humidity mixing ratio, Q/ρ, and potential temperature, θ, profiles and subregions, (b) modified index of refraction, M, profiles, (c) optical turbulence intensity, C_N^2, profiles, (d) total extinction coefficient, β (absorption and scattering), profile.

Over a time scale of 24-36 hours, physical processes within the mixed layer are also controlled by the large scale, non-stationary, synoptic flows. Synoptic scale mean vertical motion and advection will have to be prescribed or predicted over the forecast period.

The previously inferred well-mixed nature of the convective MABL has implications for the vertical distributions of mean values and the vertical flux scales of wind-U*, temperature-T* and humidity-Q*. One implication already illustrated is that properties which are conserved during mixing can be treated as being constant with height within the MABL. These parameters are the specific humidity and potential temperature for a clear MABL and equivalent potential temperature and total (vapor plus liquid) specific humidity for a cloudy MABL. A second implication is that vertical fluxes of the well-mixed parameters vary linearly with height.

These implications enable predictions of MABL evolution to be based solely on fluxes at the upper (inversion) and lower (surface) boundaries and the large scale subsidence and advection. They form the basis of recent model formulations by Deardorff (1976) and Stage and Businger (1981). Fluxes at both boundaries are due to buoyant and mechanically generated turbulence for the clear case. The linear height variations of the fluxes allows buoyant fluxes at the inversion to be more readily estimated on the basis

of general cloud features. Methods exist for estimating synoptic scale forcing from single station measurements but further efforts are required to achieve the accuracies required in MABL predictions.

In general, existing models are quite good for the clear sky MABL and fair to good for the cloudy MABL. Considerable effort is now being directed to improving the models for the cloudy MABL. The existence of cloud layers in the MABL is very sensitive to both the sea surface temperature and the entrainment rate and, in turn, clouds have a profound effect on the short and long wave radiation budget at the surface. Fairall et al (1981) provide a discussion on the approach and the status of abilities to predict the evolution of the MABL.

B. TACTICAL DESCRIPTIONS

Figures 2b-d illustrate tactical descriptions discussed in the Introduction (appearing in the right hand column of Figure1). Meteorological processes and features relevant to these tactical descriptions are those that were discussed above (Figure 2a and column 4 of Figure 1). Several meteorological factors affect each tactical description as indicated by the numbers, 1-4, in Figure 1. A few of the significant properties and values in the tactical descriptions are described in the following paragrapns.

The M profile in Figure 2b describes the refracted EM ray radius of curvature, relative to the earth's radius of curvature. If M decreases with height, a trapping layer is formed because the EM ray will bend downward relative to the earth. This causes the formation of a duct. The upper boundary of the duct is at the M minimum; the lower boundary is at the height where this same value of M occurs below the trapping layer, as shown in Figure 2b. The M profile is determined by pressure, temperature and humidity profiles, so values of well mixed temperature and humidity determine the lower boundary of the duct. A decrease of mixed layer M value with time could cause a surface based duct to become an elavated duct as shown in Figure 2b. This could occur if the mixed layer became warmer and drier due to entrainment of overlying air. Warming and drying of the mixed layer by entrainment would also increase the height of the evaporation duct, a ducting layer immediately adjacent to the surface. Examples of extended ranges and holes occurring with a duct appear in Figure 3 (Hitney, 1979).

The Cn2 profile in Figure 2c shows the vertical variation of turbulence which would affect optical wave front distortion. We see that Cn2 is largest near the surface and in the inversion. Values in these regions are 1-2 orders of magnitude larger than those in the mixed layer and above the inversion. Cn2 values near 10(-14) m -2/3 are representative for these two regions. The importance of

this value is illustrated in Figure 4 with a simulated image of a remotely piloted vehicle as viewed through Cn2 regions of 0 (no turbulence), 10(-15), and 10(-14) m -2/3 (Kearns and Walter, 1978).

The extinction coefficient, B, profile is shown in Figure 2d. B is inversely proportional to the range of IR systems and primarily depends on the absolute humidity and the aerosol size distribution. Aerosol size distributions depend on the generation rate of sea salt particles and on the relative humidity as determined by both the moisture and temperature. Therefore, IR extinction is very dependent on the entrainment of relatively clean, dry and warm air from above the inversion and on the surface wind generation of the sea salt particles (Davidson et al, 1982). As illustrated, the extinction coefficient is large within the mixed layer and increases with relative humidity which increases with height. The increase of extinction with height is important in slant path range considerations.

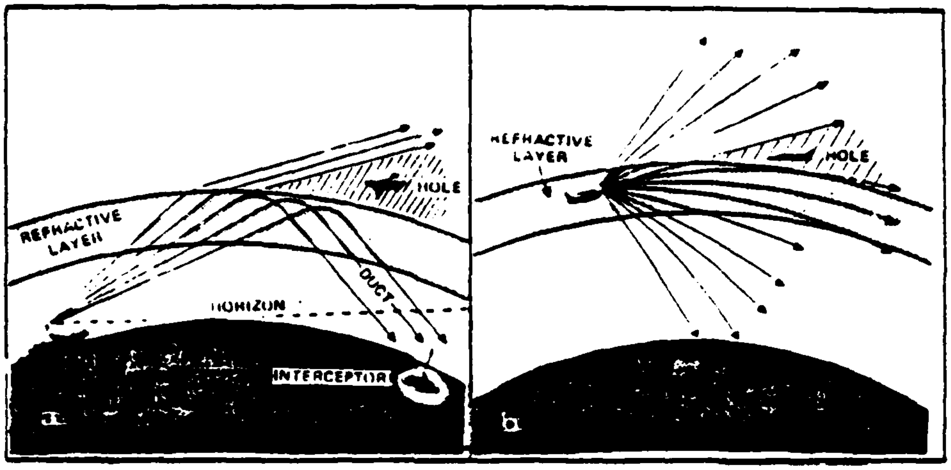


Fig. 3. Examples of extended ranges and holes for EM ducts for (a) surface-based duct and a shipboard air-search radar and (b) elevated duct and an airborne early-warning radar (from Hitney, 1979).

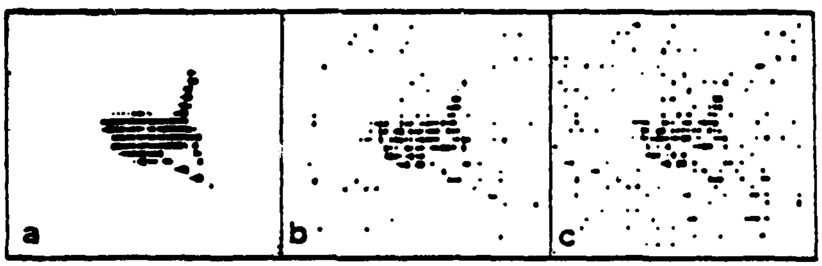


Fig. 4. Computer simulated image remotely piloted vehicle (RPV) as viewed with 8-12 m IR sensor (range 2 km, visibility 15 km, threshold 4.5 nW) through atmosphere with $C_N^{\,2}$ values of (a) 0 (no turbulence), (b) $3.7 \times 10^{-15}\ m^{-2/3}$ and (c) $1.0 \times 10^{-14}\ m^{-2/3}$ (from Kearns and Walter, 1978).

III. MABL OBSERVATIONS AND PREDICTIONS

A recently obtained data set will be used to demonstrate the prediction of changes in the MABL. The demonstration will show:

a) the status of available data sets,

b) that the assessment of relative roles of dynamic processes in the MABL can be based on a relatively simple physical model which includes specifiable inputs,

c) that, at the present time, we only have limited evidence that changes can be predicted. The rigorous specification or description will require further interpretive efforts and, perhaps, improved formulation of the separate models.

A. MABL OBSERVATIONS

The data were obtained during the Cooperative Experiment on West Coast Oceanography and Meteorology (CEWCOM-78) conducted west of San Nicolas Island, CA during May of 1978. Observations of the oceanic and atmospheric mixed layers were made from the R/V ACANIA; radiosonde observations were also made at surrounding shore stations. The data to be shown are from a 48-hour period, 5/19/1200 to 5/21/1200 PST. The R/V ACANIA was cruising slowly (2-3 knots) into the wind and returned to an initial point approximately every 12 hours. The general location of the R/V ACANIA during the 5/19 to 5/22 periods and locations of surrounding shoreline

radiosonde sites appear in Figure 5.

The period was one of steady onshore flow caused by the combined effects of intensification of the Eastern Pacific High and the persistence of the Mexican thermal low. The only apparent change in synoptic scale forcing was an increase in the offshore pressure gradient. Advection in the atmosphere was moderate. However, MABL evolutions were primarily determined by subsidence, surface fluxes, and entrainment at the inversion. Satellite imagery showed uniformly increasing stratus coverage (thin to heavy) during the period with a cellular (broken) coverage occurring late on the 21st.

Acoustic sounder returns, mean surface layer parameters, and sea surface temperature during the 19-21 May period were all measured from the R/V ACANIA and are shown in Figures 6b-d. Composite potential temperature profiles from shipboard and shore station radiosonde and temperature profiles from ship deployed XBT's appear in Figures 6a and 6e, respectively. Although these descriptions of MABL and OBL changes were obtained from an instrumented research vessel, all can be obtained from operational ships. This includes the acoustic sounder record.

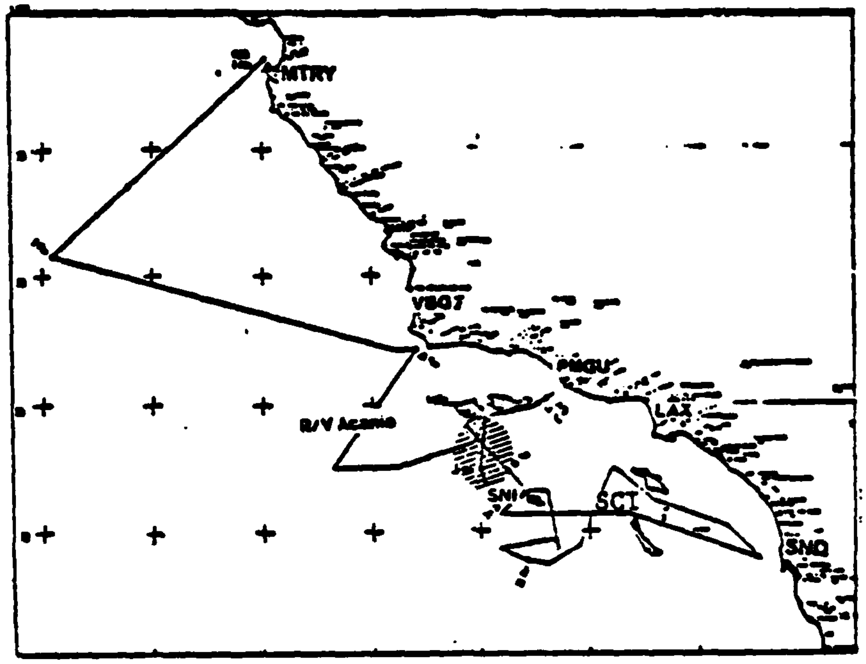


Fig. 5

Tract of R/V Acania and location of shoreline radiosonde sites during CEWCOM-78. General location of R/V Acania during 19-21 May period is indicated by hatched area N-NW of San Nicolas Island (SNI).

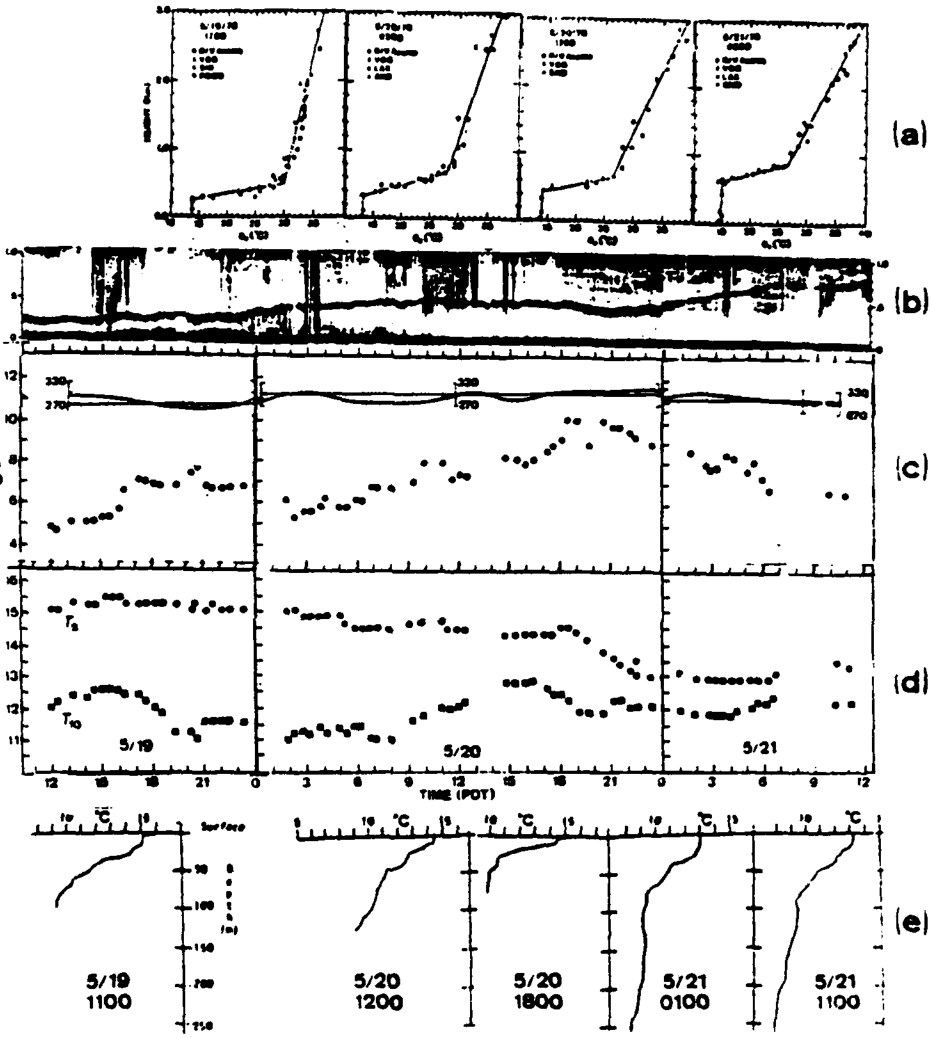


Fig. 6

Atmospheric and oceanic mixed-layer observations, during CEMCOM-78 (a) potential temperature composite profiles, (b) acoustic sounder record, (c) 10 meter wind speed, (d) 10 meter and surface temperature and (e) XBT traces. All data except indicated profiles in (a) were obtained from R/V Acania.

Changes of atmospheric features which would have been tactically significant in view of the time scale and their magnitudes were:

a) The MABL depth increased from 250 m to 750 m over the 48 hour period. The changes occurred over relatively short intervals, from 20/00 to 20/04, and from 21/00 to 21/08. The MABL depth remained nearly constant during the intervening 12 to 18 hour periods.

b) The surface layer temperature increase from 20/00 to 20/15 is indicative of entrainment of overlying warm air. The entrainment was presumably also a factor in the wind speed increase over the same period, which caused the warm shallow ocean layer to be deepened by mixing, lowering the sea surface temperature after 20/1800 (Figure 6d).

In conjunction with changes in MABL structures and parameter values depicted in Figure 6, changes occurred which are important to operational systems. Some of these changes can be determined directly from parameters measured in this scientific observational effort. M profile and cloud base heights and condensation levels can be calculated from the measured composite humidity and temperature profiles. Surface layer extinction coefficients have to be determined from the measured humidity and aerosol size distributions. The method for determining extinction

coefficients from aerosol data has been described by Schacher et al (1981). Surface layer Cn2 values and evaporation duct height can be determined with considerable certainty from measured surface layer wind, temperature, humidity and surface temperature values using expressions described by Davidson et al (1981) and Fairall et al (1978). Extinction and Cn2 profiles have to be based on more recent and, hence, less substantiated expressions such as those by Wells et al (1977) and Wyngaard and Lemone (1980).

Results from these determinations appear in Figures 7 and 8 along with the composite potential temperature, Θ, and water vapor mixing ratio, q, profiles (Figure 7a) and the inversion height (Figure 8a). The observed results indicate that for the observation period:

a) The EM duct associated with the inversion gradients evolved from being surface based to being elevated (Figure 7b) and the evaporation duct height ranged from below 5 m to above 8 m (Figure 8b),

b) Optical turbulence, Cn2, in the surface layer varied from 10(-15) to 10(-14) m -2/3 over the period (Figure 8c) and values in the inversion increased from 10(-16) to 10(-15) m -2/3 (Figure 8c),

c) Surface layer aerosol extinction in the 8-12 um IR region increased during the first 6 hours (5/19 1200-1800) because the relative humidity increased.

It decreased during the last 18 hours (5/20/1800 to 5/21/1200) because of relative humidity and wind decreases (Figure 8d),

d) Stratus clouds persisted through the period. The base lifted from about 100 m at 5/19/1800 to 600 m at 5/21/1200. This is evident in the extinction profile (Figure 7d).

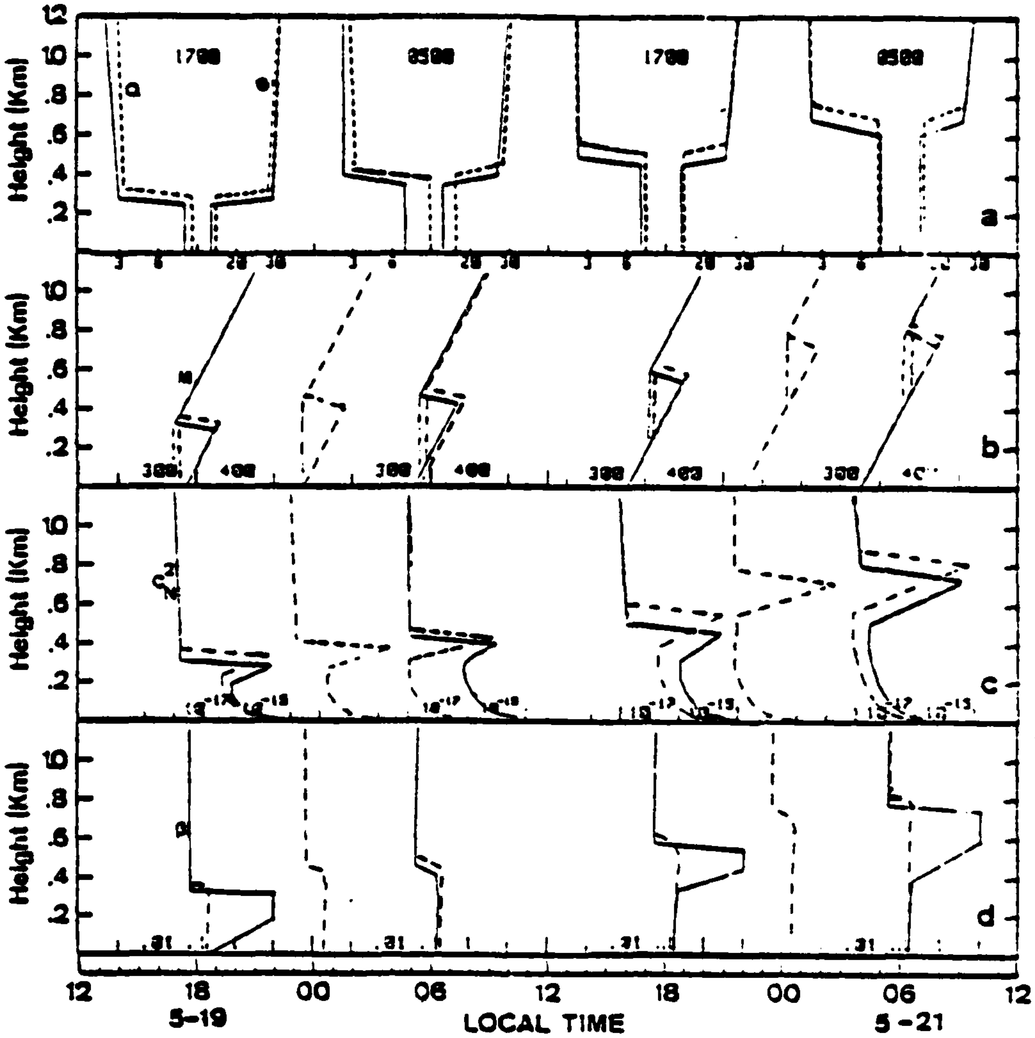


Fig. 7

Observed/computed and predicted MABL profiles for 5/19/1200 to 5/21/1200 CEWCOM-78 period including (a) Q (g m^{-3}) and θ(°C), (b) M, (c) C_N^2 (m$^{-2/3}$) and (d) total extinction coefficient, β (km^{-1}). Solid lines correspond to observed and dashed to model prediction.

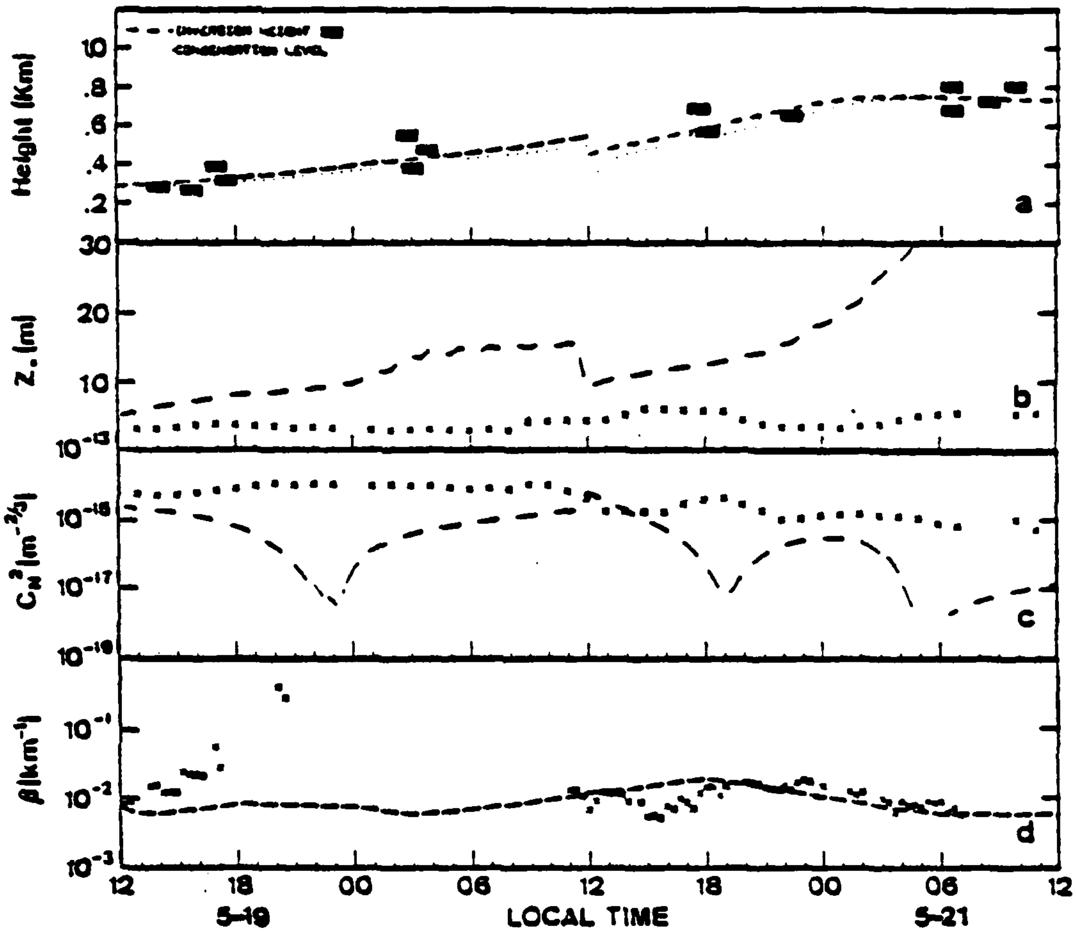


Fig. 8

Observed/computed and predicted surface layer values for 5/19/1200 to 5/21/1200 CEWCOM-78 period including (a) inversion height and lifting condensation level, (b) evaporation duct, (c) C_N^2 $m^{-2/3}$ and (d) aerosol scattering extinction coefficient, β. X's are observed and dashed lines are model predictions.

B. MODEL PREDICTIONS

During the past five years, investigations were performed on surface layer and mixed-layer scaling of small scale turbulence and aerosol properties (Davidson et al, 1978; Fairall et al, 1980; Schacher et al, 1981a and 1981b). The investigations led to the application of a time dependent MABL models based on entrainment energetics and on cloud radiative transfers suggested by both Deardorff (1976) and Stage and Businger (1981). The model requires as input an initial atmospheric sounding (radiosonde), the mean winds at a level within the surface layer (10-30 meters) and the surface temperature. Well-mixed temperature and humidity are predicted so the surface wind and wind shear at an inversion are the only local atmospheric variables which have to be prescribed. The larger scale subsidence and advection must also be prescribed for the forecast period.

The steps in the prediction computation are shown in Figure 9, where it is noted that procedures are the same for clear and cloudy cases except for entrainment computation and estimating cloud top cooling. Fairall et al (1981) include comprehensive discussions of how applicable physical processes are teated in the model and how available data can be used to estimate the processes. Because of the simplified physical model, the computations do not require numerical integration on a vertical grid so the computer storage requirements can be satisfied by available shipboard

microcomputers. In fact, the use of a hand-held calculator is being considered for these procedures. Particular computations of interest are those for the evaporation duct, the surface flux, flux of total heat and momentum and the depth change of the mixed layer. Routines for computing and graphing the M-profile can be system are used on the HP-41C/V and printer hand-held system.

Predictions of MABL changes were made with the simplified model for the 48 hour period (5/19/1200 to 5/21/1200) corresponding to observed results in Figure 6a-e. The predictions were made for two separate 24 hour periods starting at 19/1200 and at 20/1200. The initial profile for the 19/1200 starting time was that obtained at San Clemente Island (SCI in Figure 5) at approximately 1000. Initial profiles for the 20/1200 starting time were averages of the composites at 20/0500 and 20/1700. The sea surface temperatures were those at each start time as shown in Figure 6d and were 15 and 14.5 C, respectively. The surface wind observed during the forecast period was specified to increase linearly from 5 m/sec at 19/1200 to 10 m/sec at 20/2100 and then to decrease linearly to 7 m/sec at 21/1200.

Larger scale synoptic advection, was estimated to be zero from the thermal wind. Subsidence for the second period, starting at 20/1200, was adjusted on the basis of that value required for agreement between predicted and observed mixed layer depths during the first period. Hence,

the model was also used to estimate the "most probable" synoptic scale subsidence. The tuning of the subsidence value, based on comparisons of the latest sounding and predictions from a previous sounding, has been described as "hindcasting".

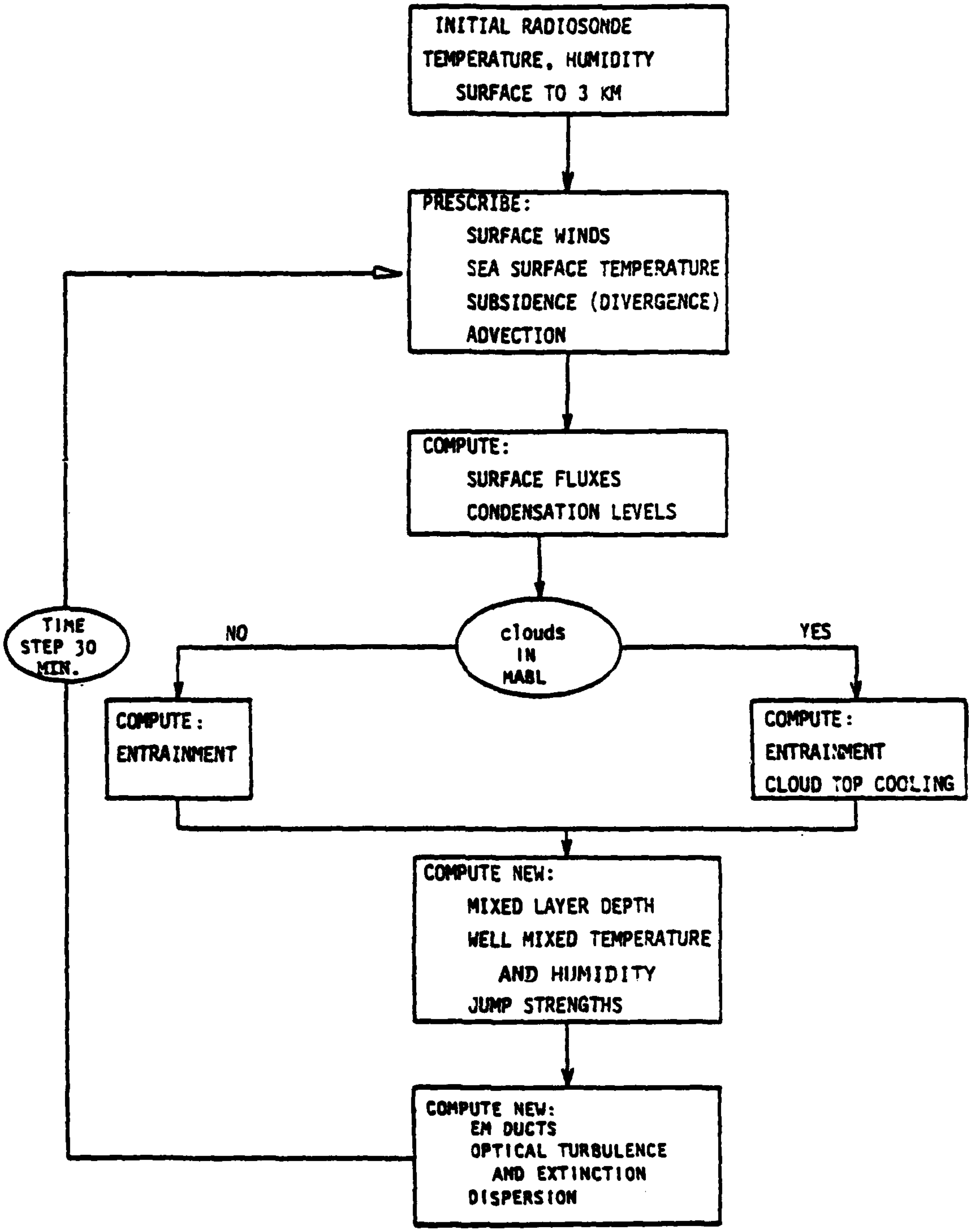


Fig. 9. SCHEMATIC OF INPUT, PRESCRIPTION AND COMPUTING STEPS IN MABL PREDICTION

The predictions are illustrated in Figures 7 and 8 along with the observed values. These predictions were made using the Deardorff (1976) cloud topped entrainment parameterization and Davidson et al (1978) surface layer parameterization. Results for the same period using the Stage and Businger entrainment parameterization appear in Appendix B. The agreement near 20/1200 in Figure 8 occurs because the model was reinitialized at that point. Significant outcomes from comparisons of observed and predicted results are:

a) The mixed layer depth (inversion height, Figure 8a) was predicted quite well. This increase during the later part of both periods was caused by cloud top entrainment because the predicted surface layer became stable and, hence, there existed no surface buoyancy flux forcing.

b) The cloud cover was accurately predicted to persist throughout the first period and for the first 15 hours of the second period, as indicated by the condensation level being below the inversion in Figure 8a. However, the predicted cloud thickness was less than that which actually occurred. As indicated in preceding discussions, the cloud cover was observed to break up on the 21st and the prediction after 21/0600 agres with that.

c) The well mixed temperature and humidity and the jump predictions (Figure 7a) are reasonable except at 20/0500. The predicted well mixed temperature was too warm by 1-2 C at all other comparison times. This led to the surface layer becoming stable when in actuality it remained unstable throughout both periods (i.e. surface temperature higher than 10 m temperature.) It is believe that the cooling associated with the clouds was not sufficient. It will be seen that the surface layer was too warm and stable during the night hours.

d) The predicted M profiles (Figure 7b) were very accurate in terms of the surface based duct evolving to an elevated duct. It is interesting that even when the predicted well mixed temperature and humidity were much too high (20/0500) the M profile was verified. This occurred because their respective affects on M were compensated.

e) The predicted Cn2 profiles (Figure 7c) gave good values for the inversion region and reasonable values for the mixed layer, except for 20/0500. Agreement within a factor of three is considered reasonable for Cn2. The inversion region values were based on the convective mixing velocity, W* (Wyngaard and Lemone, 1980) for unstable conditions. The friction velocity , U*, was used instead of W*, when a stable surface layer

existed (20/0500). Values above the inversion were set to 10(-13) for both observed and predicted profiles.

f) The total predicted extinction at 8-12 um (Figure 7d) was quite good outside of cloud layers. Again, values above the inversion were set to the same value for both observed and predicted profiles. The sensitivity of aerosol size to relative humidity becomes larger when the relative humidity is above 90%. Hence we expect this comparison to be poor in the cloud region where the relative humidity approaches 100%. However, the good agreement outside of clouds is encouraging.

g) The evaporation duct height (Z*) prediction (Figure 8b) is not very good. The disagreement occurs because the predicted surface layer was more stable than was observed. Z* increases almost linearly with increasing stability. Very large Z* values were predicted at the end of the second period because it was stable and because the predicted well mixed humidity was too low, Figure 7a.

h) The predicted surface layer Cn2 values (Figure 8c) were always less than those observed because of the previously mentioned inaccuracy in surface layer stability. Minima at 19/2300, 20/1800 and 20/0500 correspond to the surface layer being neutral as it passed from unstable to stable, unstable to stable and stable to unstable conditions, respectively.

i) The predicted surface layer aerosol scattering extinction for 8-12 um (Figure 8d) was very good during the second period. The observed and predicted decrease from 20/1800 to 21/1200 was associated with a decrease in relative humidity and wind speed. The wind speed used for the prediction was, of course, prescribed on the basis of observed results. Hence, the role of relative humidity on the extinction is that being evaluated.

C. PREDICTION INTERPRETATION AND APPLICATION

The demonstrated capability of this model, which is based on routinely observed input data, should be of assistance to the geophysics officer in estimating possible changes in the MABL and in the inversion and the potential impact upon tactically important parameters. Exploitation of the existing ducts is presently possible with IREPS. Specifically, the duct changes between elevated and surface based nature are of considerable concern to placement of platforms to enhance or to minimize communication links. Alerting commanders and airborne assets in advance to possible changes is a capability not previously available in on board assessment systems. Of additional use is the computation of the lifting condensation level to indicate the occurence of clouds.

IV. CONCLUSIONS

The importance of and an approach for predicting evolutions of the marine atmospheric boundary layer have been described. Changes in the mixed layer depth strengths of overlying inversion and well-mixed properties lead to significant changes in the weapons/systems tactical environment. These include EM duct regions, optical turbulence and optical extinction, both within and at the boundaries of the inversion capped mixed layer.

Although the tactical descriptions are multi-variable and require detailed vertical descriptions, a simplified model based on routinely observed data appears to be quite useful for predicting changes over 12-18 hours. For a cloud topped period, it was demonstrated that the refraction, optical turbulence and optical extinction profiles were predicted quite well, as were cloud coverage changes.

The primary differences between observation and predictions were for the near surface layer and pertain to the evaporation duct height and the optical turbulence. The predicted evaporation duct was much too high and the predicted optical turbulence was much too low. In both cases, the predicted air temperature was too high (2-3 C) which resulted in a neutral to stable condition. The cause for this appears to be due to improper specification of

cloud cooling within the mixed layer. This is an area in which research is still being performed.

Two schemes are presently being evaluated for specification of cloud top cooling and entrainment, Stage and Businger (1981) and Deardorff (1976). Both address entrainment and cloud top cooling for short and long wave radiation, but large disparities exist in actual parameterization. More study in the variance of absorption with insolation and cloud buoyancy should resolve the difference. Both of these effects may have great impact on the predicted results because of the bulk nature of the model employed.

Tactical decisions can only be made with timely, pertinent and accurate information. The specific information presented by this model can be extremely important to temporal and spatial variation of ducting and refraction. As a bulk model, it is a gross approximation to actual conditions, but affords decision makers an estimationof most probable relevant changes in the meteorological conditions.

APPENDIX A

OPERATING PROCEDURES FOR THE MODEL PROGRAM

MODEL USAGE PROCEDURES

1. Model Components and Flowchart

Using this code requires minimal knowledge of microcomputer systems. Inputs required are an initial radiosonde (IREPS), forecast winds (up to 30 hours), and subsidence (divergence) and thermal advection. Because of forecasting, some ability to estimate large scale subsidence and advection is required.

1.1 Model Components.

A block diagram and flow chart for the program appear in Fig. A-1 and A-2, respectively. The block diagram (Fig A-1) gives an overview of the program operation and flow, as broad as possible without specifics. The flow chart can be useful to keep track of position within the execution of the program. The program flow (Fig A-2) was designed to be as autonomous as possible, yet enable the user to interface with the precedure as deemed necessary. The two critical points in program flow are the input of subsidence and selecting an initial, simplified model for the atmospheric structure (digitizing).

The following sections include separate discussion of program operation, initial parameter input, selection of

output, and procedures for adjusting inputs to produce meaningful output.

1.2 Overview of Model Flow

The first list of items for selection is the DIRECTION MENU from which the user selects the operation to be performed. The operation can be to:

1) Predict the change of the inversion,

2) Display the predicted results, graphics or tabular form,

3) End prediction model and rewind tapes,

4) Return to IREPS,

5) Review or Change any initial conditions, then rerun the prediction model.

Any data set on an IREPS data tape can be called. The prediction would normally be the first choice in a procedure. In the prediction procedure (choice 1), the computation loop steps are:

1) Choose the IREPS data set,

2) Enter forecast winds and other initial conditions,

3) Approximate a stick structure to the temperature and specific humidity profiles from the selected IREPS data set.

Do not use IREPS bailout keys to correct errors.

EXCEPTION: User Defined Key 1 will take the user back to the DIRECTION MENU.

Once all the computations have been performed for a forecast period, the program will return to the DIRECTION MENU. If the display (2.3) is selected at this point, the user may select displays of various computed values. Selection may be of the inversion height change and 'M' profiles at spaced intervals or the inversion strength 'jumps' and well-mixed temperature and specific humidity or a tabular print out of the computed parameters. After each of these displays are completed, the program will return to the DISPLAY MENU for a choice of different display or return to the DIRECTION MENU.

The user may also use the DIRECTION MENU to choose a different value for subsidence or other parameters by going through the REVIEW/CHANGE MENU. The prediction model must be run after changes are made to produce new outputs.

In the following section we will consider the program steps, the block diagram should be used to follow the discussion.

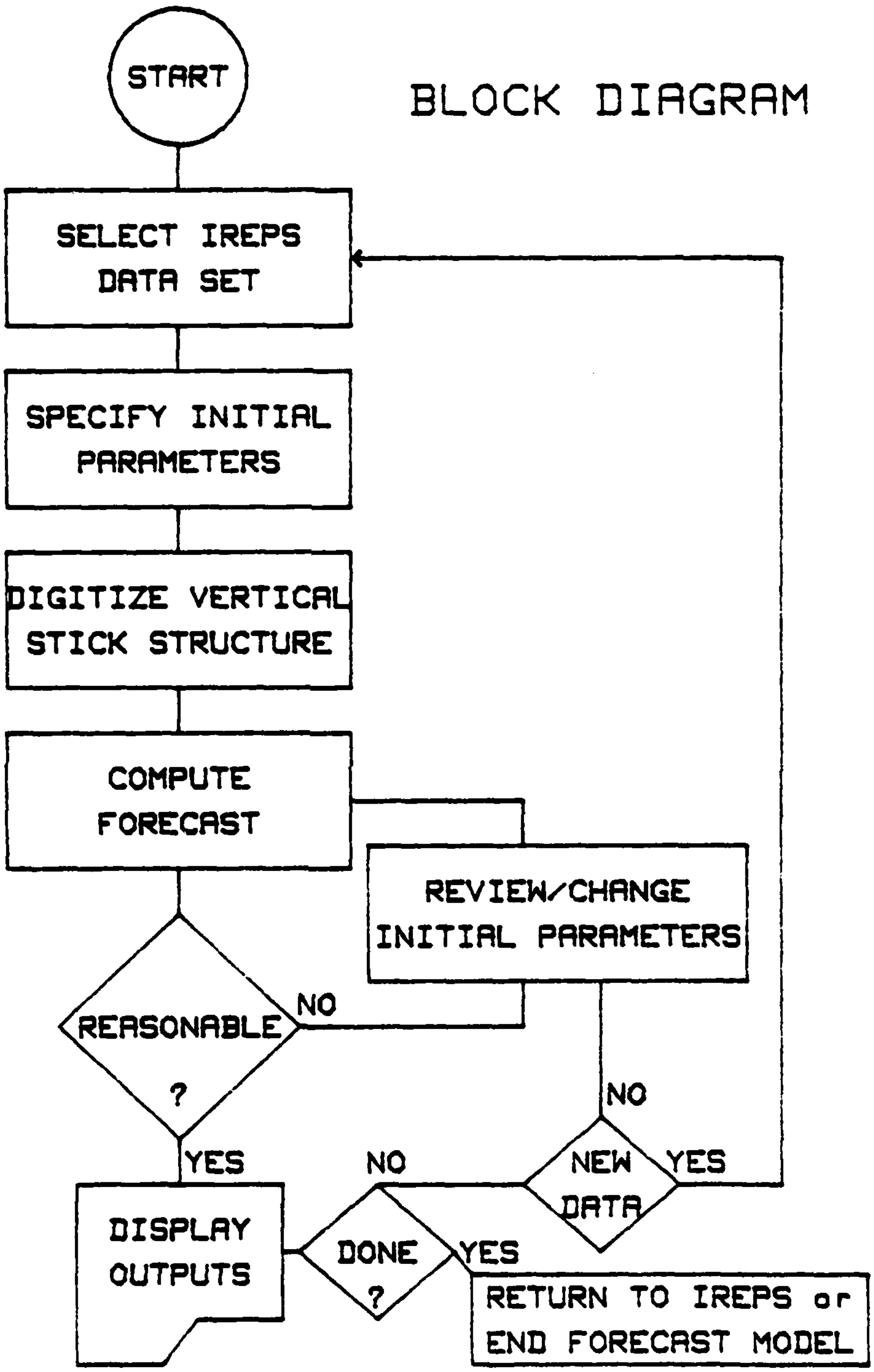


Fig. A-1. PROGRAM BLOCK DIAGRAM

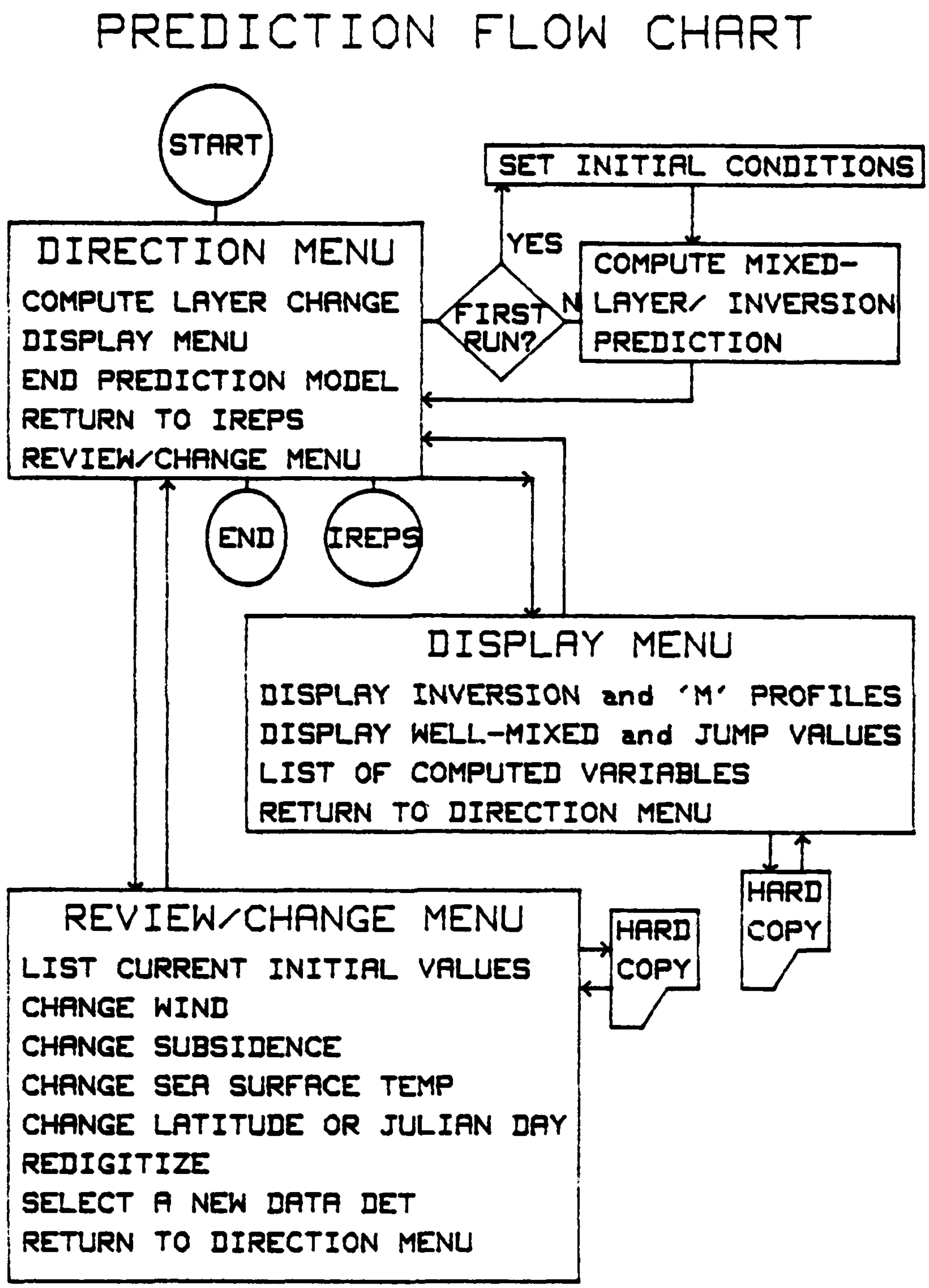


Fig. A-2. PROGRAM FLOWCHART

2. PROGRAM EXECUTION STEPS

2.1. Starting Procedures

2.1.1 Loading and Starting Program

The prediction model program is loaded by typing:

LOAD "MIXED2:xxx",1   then EXECUTE

Where xxx is the proper mass storage device (e.g. T14) containing the model program.

NOTE

In default, the program will look for the data tape to be in the left hand tape drive (T14).

Questions requiring user response will be set off by asterisks, the selection menus can be viewed on the flow diagrams or at the beginning of each major section.

2.1.2 Enter Execution Date

****

ENTER Execution Date as date of forecast run, just press CONT if the same

****

The entered date will be printed on all displays to indicate the date of run, this is not necessarily the date of the data set. If it is left blank, the date will default to that of the IREPS data set (i.e. IREPS date if IREPS has just been run, blank if this program is run alone.) The computer will then read the IREPS data table and display the DIRECTION MENU.

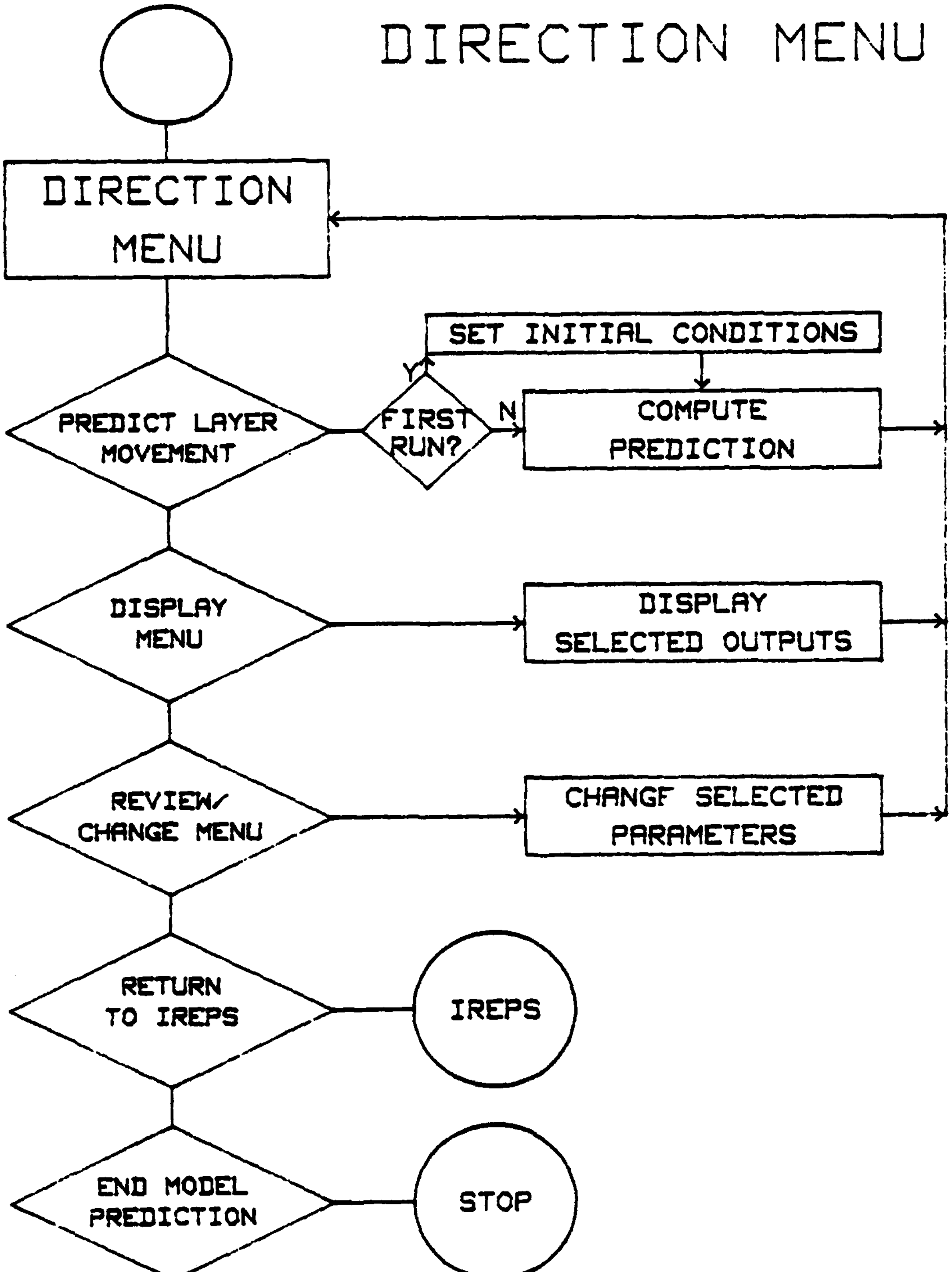


Fig. A-3. DIRECTION MENU FLOWCHART

2.2 DIRECTION MENU

Choices of procedures are:

1) COMPUTE THE LAYER CHANGE

2) DISPLAY THE OUTPUTS

3) END THE PREDICTION MODEL

4) RETURN TO IREPS PROGRAM

5) REVIEW/CHANGE ANY INITIAL CONDITIONS

****

ENTER option (1 to 5) then press CONT

****

2.2.1. COMPUTE THE LAYER CHANGE.

The list of data sets on the IREPS data tape is presented and the selection is made by entering the corresponding line number, followed by CONT.

2.2.1.1. Data Set Choice

****

ENTER THE NUMBER OF THE DATA SET DESIRED

****

If the desired data set is not on the present data tape, hence is not displayed, SFK 1 (k1--top right of keyboard) should be used to return to the DIRECTION MENU, or type 'CONT Option', then EXECUTE. If a different data tape is to be used, insert it in the left tape drive and restart the program with STOP and RUN. Otherwise, the program will retrieve the entered choice of data set and proceed toward the next procedure which is digitizing. The program will

ask for winds (2.2.1.4.), subsidence (2.2.1.5.) and the sea surface temperature (2.2.1.6.).

2.2.1.2 Latitude and Julian Day

The program uses these two inputs for calculating the zenith angle of the sun and thus the amount of insolation at the top of the inversion or cloud layer.

****

ENTER Latitude of the prediction area [-90 to 90] [use - for South]

****

ENTER the Julian day of the year [maximum 3 digits]

****

2.2.1.3 Beginning Time

****

ENTER THE BEGINNING TIME [4 digits]

****

The beginning time will be displayed on all the output. The entered time should be fairly close to the start time since it determines the beginning of the 30 hour forecast period. The entered time must have four characters (e.g. 1900). The program displays will only be in whole hour segments for easier graphic interpretation.

2.2.1.4 Wind Forecast

****

IS THIS WIND FROM IREPS OKAY (Y/N)?

****

The program will display the initial time and the wind speed as previously entered in the IREPS data set. If the wind is to stay the same, press CONT with no entry, the response will default to the first of the options. If the wind is to be changed, enter 'N', press CONT, in which case the following question will ask for a new beginning wind speed.

****

ENTER BEGINNING WIND SPEED [KNOTS] at time XXXX

****

Winds are requested in KNOTS. The code performs computations with wind in m/s, a conversion is performed, (c.f. Appendix C.) The display is now set up to enter forecast winds for the period. (Fig B-1)

****

hhmm,ww FROM THE FORECAST, ENTER: TIME,WIND (KNOTS)

****

The maximum number of winds USED is 10. When done entering winds, enter 'E' or 'END'. Winds will be linearly interpolated between input times. This is a gross approximation, but works well with the degree of accuracy used in forecasting winds. To get a smoothing closer to the forecast, enter more winds at the times of rapid change. If the fine structure is available or needed only for the first part of the period, enter the winds as desired. If the last

wind entered is for a time before the end of the period it will be held constant to the end of the period.

If the initial wind is to be used throughout the period, enter 'E' or 'END' as the first response to this question. As a prompt, the time of the last possible input period, 30 hours after the beginning time, is displayed. All times must be entered sequentially, times beyond the last period will not be considered.

****

DO THESE WINDS LOOK OKAY (Y/N)?

****

If different winds are desired, the computer will ask for correction of entered winds, one line at a time. If the displayed winds are correct, press CONT, if not, enter N and refer to the previous qestion. The next requests will be for subsidence, and a check of sea surface temperature. The program flow will then proceed to digitizing.

2.2.1.5: Subsidence Forecast

****

ENTER SUBSIDENCE (m/sec) [First value=-.003], or CONT to use same value?

****

Enter a value of subsidence in meters per second. This can be calculated from the divergence field, determined explicitly from the previously used value or by manipulating this model between successive soundings.

2.2.1.6. Sea Surface Temperature Specification

****

ENTER THE SEA SURFACE TEMP IN °C or just CONT for same value

****

The sea surface temperature from IREPS, which is displayed, may need refinement from the initially entered value. This would arise if the temperature used in the IREPS data set was the sea water injection temperature. To use the existing value, just press CONT without entering anything. To change the value, enter the new temperature in degrees centigrade, and press CONT.

2.2.1.7 Profile Initialization

The program will now go to the digitizing, the determination of the vertical structure of potential temperature and specific humidity. The steps establish:

Inversion height

Potential temperature

(well-mixed, jump and lapse rate values)

Specific humidity

(well-mixed, jump and lapse rate values)

Previous inputs will be dislayed on the plot. One display with data and digitized results appears in Fig.B-2. At the end the user will be asked to specify whether the plotting is OKAY or if he wants to do it AGAIN, if an error

is made during the digitizing routine, continue to this question, then redigitize.

The program will draw out the digitizing graph and its labels, then enter the digitizing mode. The first structure to plot will be the potential temperature, the second will be the specific humidity. The profile data, taken from the IREPS data tape, will be displayed to 2400 meters or the maximum height of entered data if less than 2400 meters. When digitizing can begin, the computer will beep and a full screen cursor will appear. To position the cursor, use the arrow keys at the top, center of the keyboard, then CONT.

NOTE

Finer structure is achieved by using shift when positioning the cursor. This will move it one pixel, or picture element, at a time.

2.2.1.7.1. POTENTIAL TEMPERATURE: θ

1a) Inversion Height: position the horizontal line at a representative inversion height (usually near the middle of the sharp temperature 'jump'.)

1b) Well-mixed Temperature: position the vertical line at a representative value for the well-mixed temperature below the inversion, then CONT. POINT 1

2) Inversion 'jump': horizontally position the small cursor at the point where the

extension of the profile above the layer meets the horizontal 'jump' line at the inversion height (use precision eyeball), then CONT. POINT 2

3) Gradient Above the Inversion: position the small cursor at the top of the screen or heighest data point to get the best linear approximation of potential temperature above inversion, determining lapse rate, then press CONT. POINT 3

2.2.1.7.2. SPECIFIC HUMIDITY: Q

1a) The inversion height determined for the potential temperature sequence will be the same for the specific humidity procedure. POINT 4

1b) Well-mixed Specific Humidity: position the vertical line at a representative value for the structure below the inversion, then CONT. POINT 4

2) Inversion 'jump': position the cursor where the extension of the profile above meets the horizontal 'jump' at the inversion (again, this is very subjective), then CONT. POINT 5

3) Gradient Above the Inversion: position the small cursor at the top of the screen or highest data point to get the best linear approximation of the specific humidity above the inversion, determining lapse rate, then press CONT. POINT 6

ENVIRON. DATA LIST, FROM MIXED2   NPS   05/20/78/0430

WIND	6.7	AIR TEMP	11.3
SEA TEMP	15.0	REL HUM	97.7
SFC PRESS	1013.1	IREPS EVAP DUCT HT	5.9

LEVEL	PRESS	TEMP	RH %	METERS	M UNITS	POTENT TEMP	SPEC HUM
1	1013.1	10.9	93.0	6.0	334	11.0	7.3
2	1000.0	10.7	93.0	114.7	347	11.8	7.2
3	972.0	9.0	93.0	351.2	372	12.4	6.4
4	954.0	11.1	22.0	506.7	353	16.1	1.7
5	947.0	18.4	20.0	568.9	360	24.0	2.5
6	944.0	18.9	20.0	596.0	363	24.7	2.6
7	923.0	19.4	19.0	789.0	387	27.1	2.6
8	850.0	14.9	24.0	1490.9	481	29.5	2.4
9	754.0	9.9	19.0	2494.7	609	34.3	1.4
10	700.0	7.8	19.0	3109.3	691	38.3	1.2

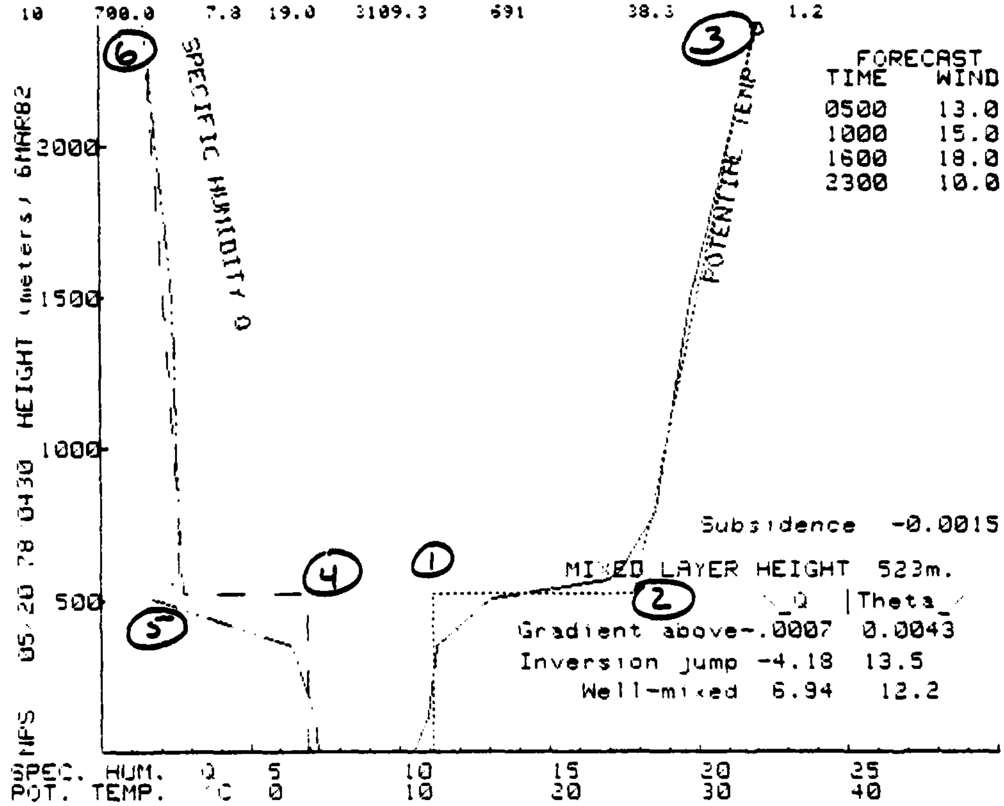


Fig. A-4. EXAMPLE OF DIGITIZED VERTICAL STRUCTURE

ENVIRON. DATA LIST, FROM MIXED2 SCI 10 03 76 1400 SCI

WIND	5.1	AIR TEMP	23.9
SEA TEMP	15.0	REL HUM	60.0
SFC PRESS	1013.1	IREPS EVAP DUCT HT	22.6

LEVEL	PRESS	TEMP	RH %	METERS	M UNITS	POTENT TEMP	SPEC HUM
1	1013.0	23.9	58.0	5.9	338	24.0	10.4
2	1000.0	19.9	70.0	118.2	354	21.1	9.8
3	976.0	16.5	83.0	326.8	382	19.7	9.4
4	954.0	14.9	79.0	520.8	399	20.0	8.0
5	929.0	14.9	56.0	745.9	410	22.2	5.7
6	907.0	15.7	53.0	949.2	435	25.0	5.7
7	879.0	14.4	41.0	1214.8	458	26.3	4.0
8	850.0	14.0	26.0	1497.9	484	28.7	2.5
9	807.0	12.9	10.0	1934.3	529	31.9	.9
10	765.0	11.1	10.0	2381.0	589	34.4	.8
11	717.0	8.4	10.0	2918.3	661	37.0	.7
12	700.0	9.2	10.0	3116.6	687	39.7	.7

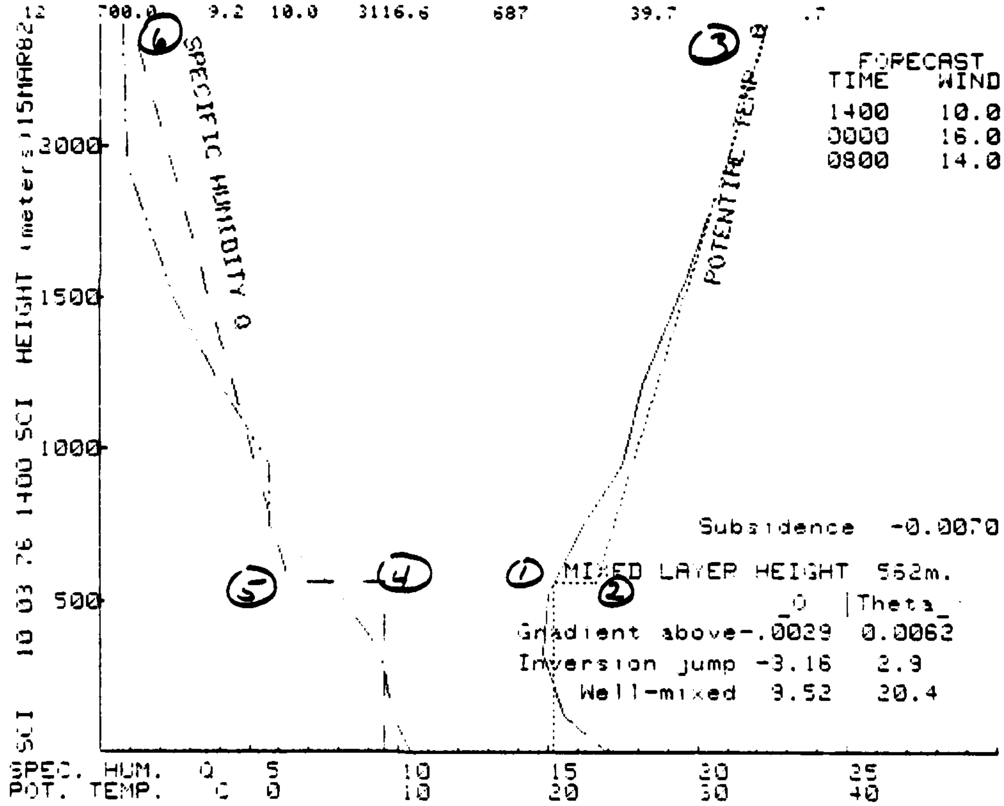


Fig. A-5. EXAMPLE OF DIGITIZED VERTICAL STRUCTURE

If the digitized plot is not as desired, move the cursor to AGAIN, press CONT, and begin with POTENTIAL TEMPERATURE (2.2.1.6.1). If the digitized plot is agreeable, move the cursor to the OKAY and press CONT. This will start the program into the computing stage. A picture of the layer computatutions is progressively displayed.

At the completion of the run the program will return to the DIRECTION MENU. The running prediction may be PAUSEd at any time, then k1 or 'CONT Option', 'EXECUTE' will take the program back to the DIRECTION MENU.

2.2.1.8. Change Subsidence or Other Initial Parameters

A decision point exists here as to the reasonableness of the layer movement. If it looks good, choose to display the change (2.2.2.). If the results of the computation do not go as expected, choose to re-compute using a new value of subsidence or other initial data, or redigitize the vertical structure. Both can be performed by choosing REVIEW/CHANGE MENU (2.2.5.). Use of the flow chart can be helpful when running the program.

2.2.2. Display the Outputs

Selection of this option will take the user to the DISPLAY MENU for more defined and varied displays of computed inversion layer movement:

1) overall display of inversion movement and M-profiles

2) the inversion jumps of temperature and humidity

3) tabulation of selected values through the period

Refer to paragraph 2.3 DISPLAY MENU

2.2.3. End Prediction Model and Rewind the Tapes

This choice will simply rewind the tapes in the computer and end the prediction model program. Remember to use the EJECT bar to remove tapes.

2.2.4. Return to IREPS

This choice will take the user back to the IREPS program. The IREPS driver tape must be in the right hand tape drive, before pressing CONT, to load successfully.

2.2.5. REVIEW/CHANGE MENU

This option is for rerunning the program with different values for initial data. This can also be used for going through the digitizing routine and retaining the winds that were input. When the end of the digitizing routine is reached, the user will again be given the choice of changing the digitized points. If all looks satisfactory, press CONT which will return the program to this menu. This procedure can be continued until a good approximation is generated.

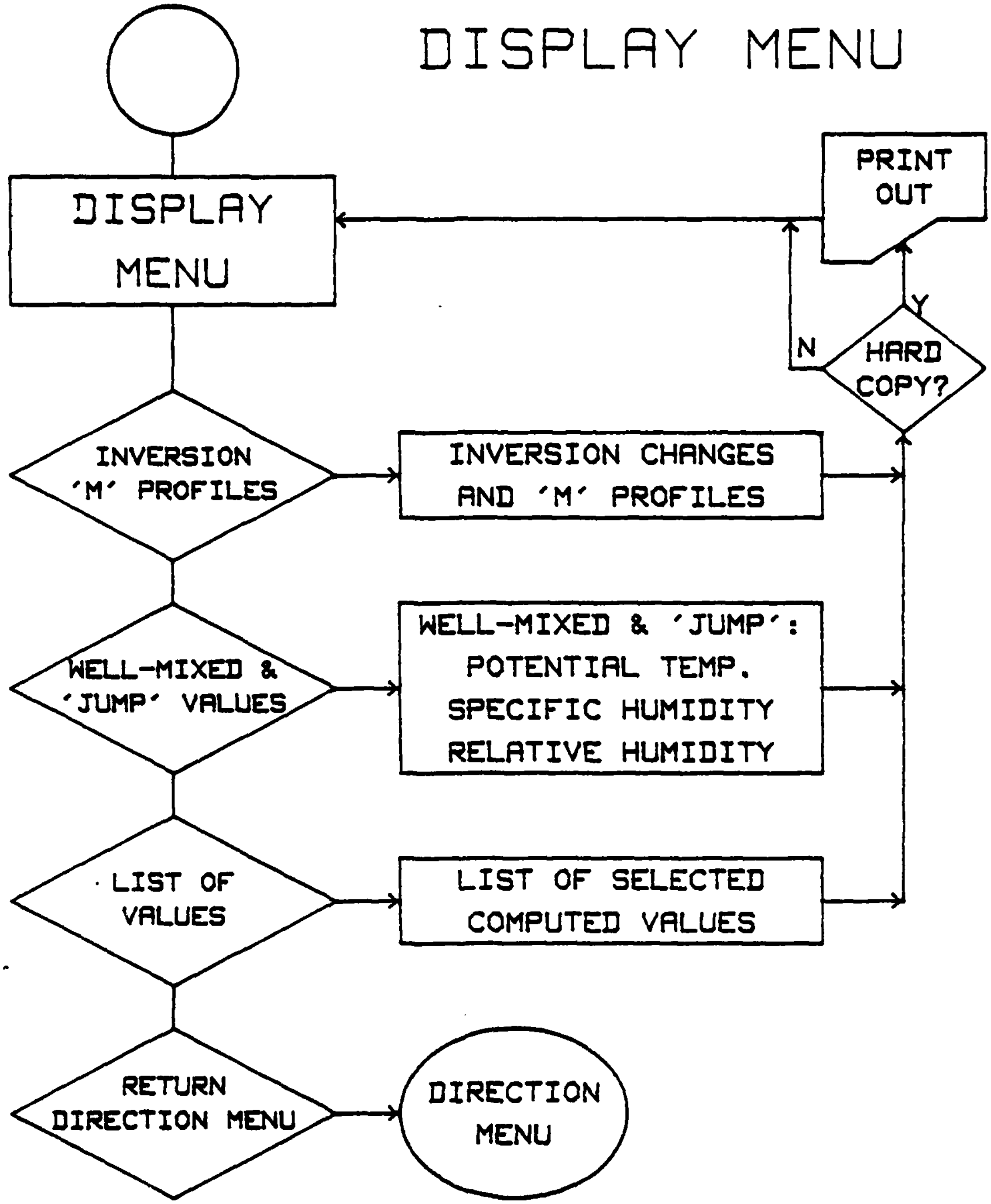


Fig. A-6. DISPLAY MENU FLOWCHART

2.3. DISPLAY MENU

The following options will be listed:

1	DISPLAY OF INVERSION AND 'M' PROFILES	graphics
2	'JUMP' STRENGTH AT INVERSION	graphics
3	LIST OF COMPUTED VALUES	tabular
4	RETURN TO THE DIRECTION MENU	

****

ENTER display choice then press CONT

****

The user will be asked of he wants hard copy, after the graphics displays are drawn and before the tabular listing is run. Option 4 will take the program back to the DISPLAY MENU as will SFK 1 at any time. Further discussion and interpretation of the various aspects of the displays occurs in Appendix B.

2.3.1. Graphics Display of Inversion and 'M' Profiles

As the main graphic product of the prediction, this display depicts the changes, over the 30 hour period, in the inversion height, the lifting condensation level (for cloud formation), the relative humidity and the 'M' profile (modified index of refraction) indicating elevated and surface based duct conditions.

2.3.2 Graphic Display of Jumps and Well-Mixed Values of Potential Temperature and Specific Humidity

To illustrate the change in inversion strength, this display graphically shows the variations in the well-mixed

values next to the 'jump' values of both potential temperature and specific humidity. Also displayed is the relative humidity as it evolved through the forecast period.

2.3.3 Tabular Display of Selected Parameters

This option lists the values that are stored during computation to be used for generating graphic displays. They are useful to more fully understand the movement of the inversion, the change in the duct area and the inversion strength.

2.3.4 Return to the DIRECTION MENU

This option will return the program to the DIRECTION MENU for further choices to compute again, return to the IREPS program or just end the prediction model.

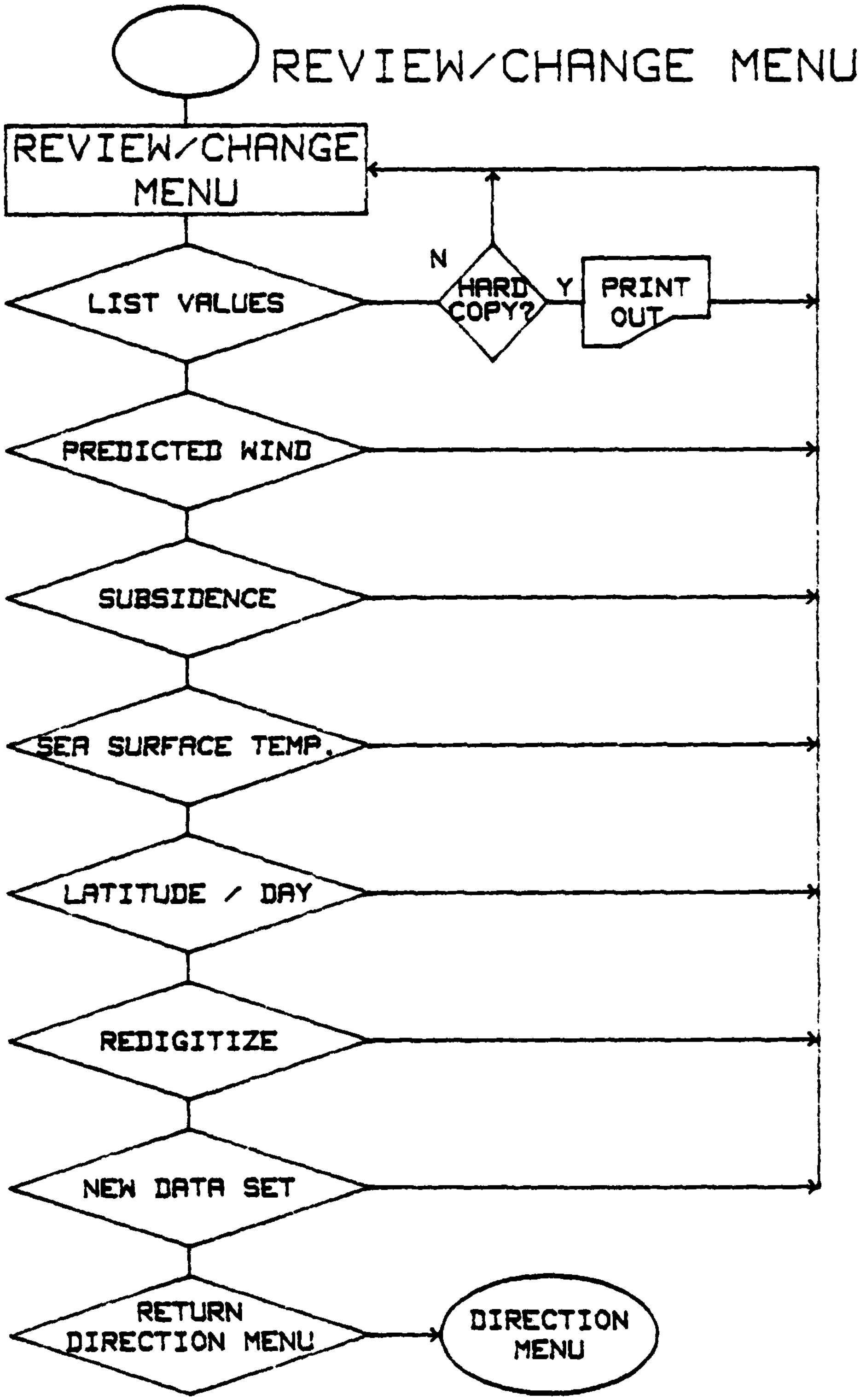


Fig. A-6. REVIEW/CHANGE MENU

2.4 REVIEW/CHANGE MENU

Select one of the following to change a parameter after which the prediction needs to run again:

1) List Current Initial Values
2) Change Wind
3) Change Subsidence
4) Change Sea Surface Temperature
5) Change Latitude or Julian Day
6) Redigitize the Vertical Structure
7) Select a different data set
8) Return to the DIRECTION MENU

Once this option is exercised, the model must run through another prediction before drawing out any displays.

****

ENTER choice from REVIEW/CHANGE MENU (1-8)

****

2.4.1. List Current initial Values

This will list the values of the indicated variables that were last used or modified. The user will be preompted to get a hard copy. Default of the question will be to the CRT, press CONT when ready.

2.4.2. Change Wind

Refer to procedure 2.2.1.3 and 2.2.1.4 and the return to REVIEW/CHANGE MENU.

2.4.3. Change Subsidence

Refer to procedure 2.2.1.5, return to REVIEW/CHANGE MENU

2.4.4. Change Sea Surface Temperature

Refer to procedure 2.2.1.6, return to REVIEW/CHANGE MENU

2.4.5. Change Latitude or Julian Day

Refer to procedure 2.2.1.2, return to REVIEW/CHANGE MENU

2.4.6. Redigitize the Vertical Structure

Refer to procedure 2.2.1.7, return to REVIEW/CHANGE MENU

2.4.7. Select a New Data Set

Choosing a new data set will take the program through all the initial steps to set up the necessary parameters to make a prediction model run.

2.4.8. Return to DIRECTION MENU

This option will return the program to the DIRECTION MENU for further choices to compute the forecast again, return to the IREPS program or end the prediction model.

APPENDIX B

PREDICTION OUTPUT

This appendix contains examples of the prediction output which are obtained by making selections from the DISPLAY MENU for output. Two different prediction runs are shown, each for a different observational period. The two periods were a cloud covered case, previously discussed in the body of the thesis, and a clear sky case, described by Davidson et al (to be submitted, JAM, 1982).

Entrainment energetics for the cloud covered case in this appendix were based on fomulations by Stage and Businger (1981). Results for the same period were shown in the body of the thesis, but were based on a formulation by Deardorff (1976). The scope of this thesis was not to compare the differences between the entrainment parameterizations. Such a comparison will be performed separately by Naval Postgraduate School investigators.

Prediction output examples appear in two sets, one for each prediction period. Each set contains a listing of several computed variables and two pages with graphic plots of several computed variables and/or profiles. The plotted variables do not encompass all those listed. All selected outputs automatically appear on the CRT, and the printed copies (hard copy) may be obtained by selecting the appropriate option after CRT display.

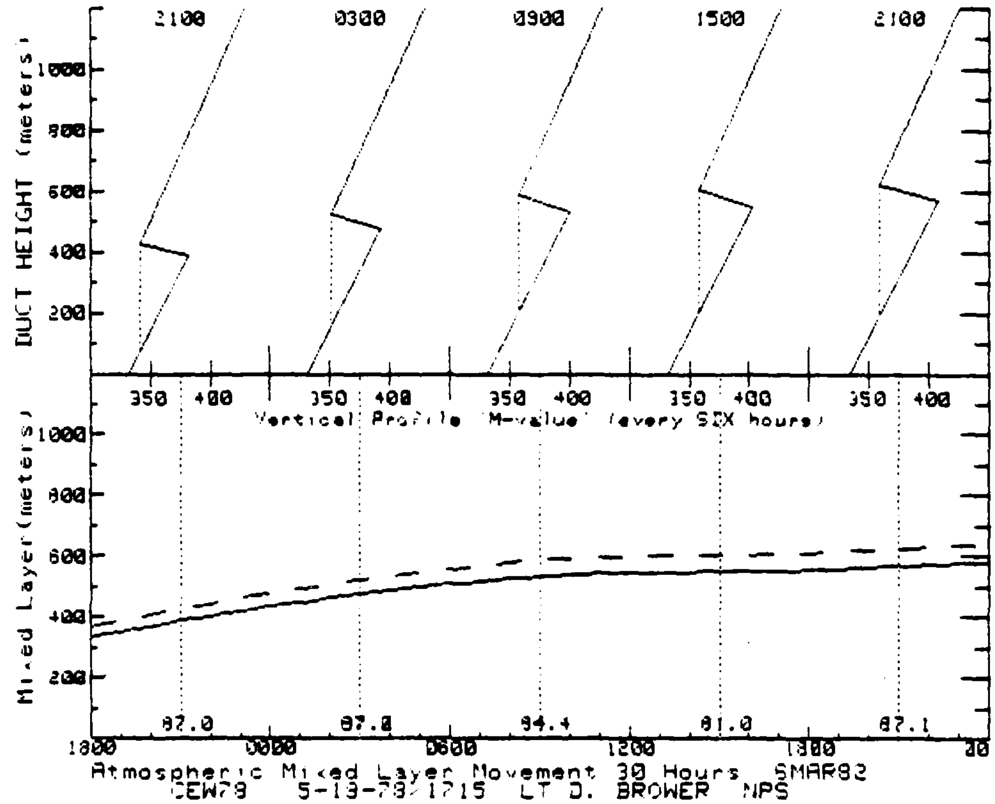
The listing of predicted results (Fig. B-3 and B-6) are self-explanatory. The listed values are for every 30 minute period (the prediction time step) and the units are: velocity-m/s, temperature-Kelvin, height-m and humidity-g/kg.

The graphic plots contain information about the predicted vertical structure (Fig. B-1 and B-4) and the predicted values in the mixed-layer and at the inversion (Fig. B-2 and B-5).

The predicted vertical structure is presented in two panels in Fig. B-2 and Fig. B-4. The top panel shows predicted M profiles (Modified index of refraction) at 6 hour intervals, including possible surface based duct conditions. It is determined from the predicted well-mixed T and q and the predicted jumps at and lapse rates above the inversion. The bottom panel shows the top of the well mixed layer (-----), the top of the inversion zone (- - -) assuring an inversion thickness of .1 layer height and the lifting condensation level (.....). The lifting condensation level was computed from the well mixed temperature and specific humidity values. A description of duct determination appears at the bottom of the hard copy page.

The graphic display of predicted values (Fig. B-2 and Fig. B-5) in the mixed layer and at the inversion are of several variables appearing in the listing option. The solid lines in the top panel represent the well mixed values

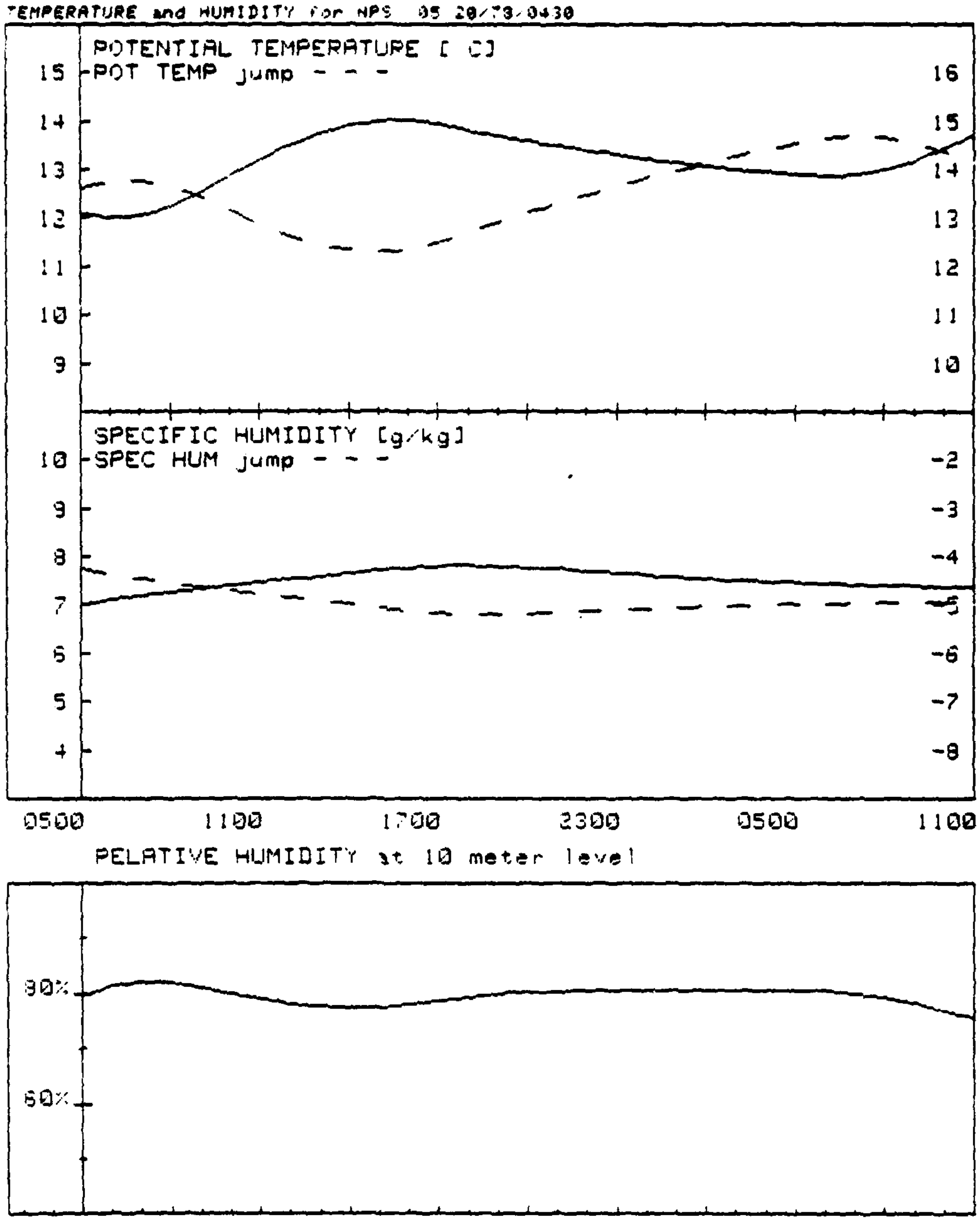
in the layer appropriate for the 10 meter level. The dashed lines are the 'jump' of that parameter (T or q) at the inversion. The 'jump' magnitudes are important in determining the strength of the duct and its depth. The <u>bottom panel</u> shows the relative humidity at the 10-meter level. It can be used to determine the proximity of fog or clouds and would be important in aerosol equilibrium size determination.



This is a SIMPLIFICATION of the real structure.

This display is divided into UPPER and LOWER windows:
LOWER WINDOW displays the top and middle of the elevated layer and its forecast continued movement for a thirty hour period after beginning.
At the bottom is the Relative Humidity at each six hour period.
The lightly dotted line is the lifting condensation level.
[With enough moisture near the inversion, this can be used as a flag for possible cloud formation, or for high mixed-layer humidity, near the surface, to forecast fog.]
UPPER WINDOW picks out M-value structure (using only 4 points) at each six hour period and will indicate a surface based duct only if the elevated M-value is less than or within 5 of the surface M-value. The sampled times are displayed at top.

Fig. B-1. Vertical Profile and "M" Profiles- Cloudy Sky



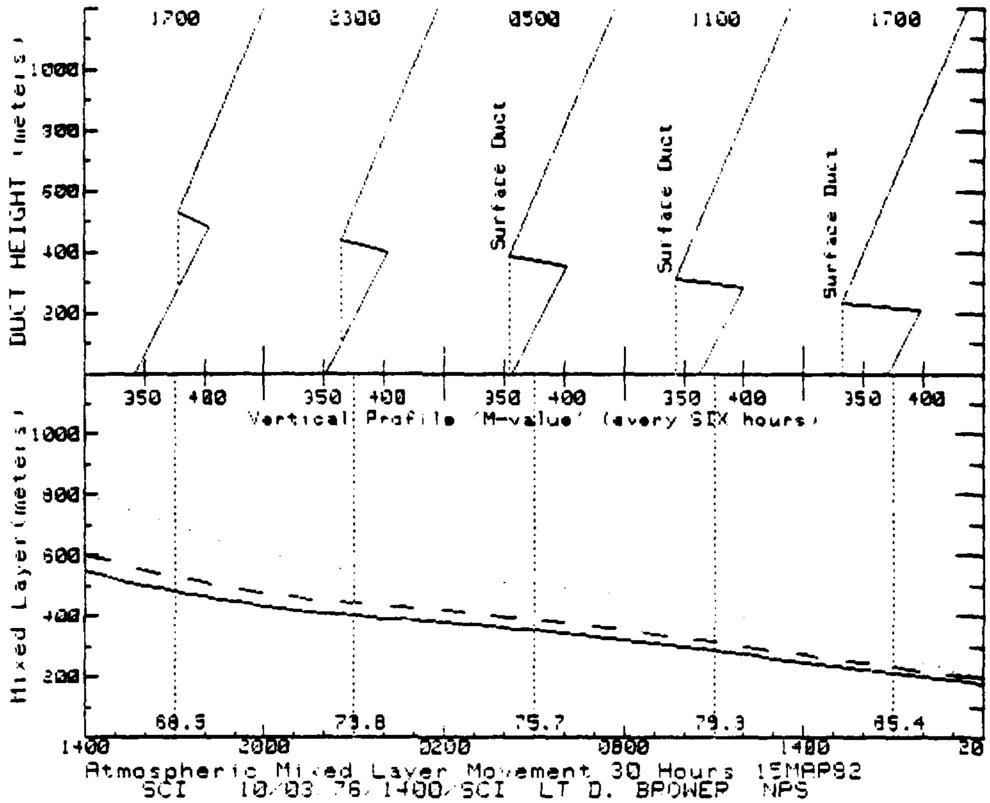
30-HOUR PREDICTION OF POTENTIAL TEMPERATURE AND HUMIDITY
The well-mixed value scale is along the left, the jump value scale is along the right. The third frame is Relative Humidity.

Fig. 3-2. Mixed Layer and 'Jump' Values-Cloudy Sky

This is a list of plotted values. NPS 05/20/78/0430 5MAR82

HOUR	Zi	Zicl	RelHum	WIND	Th	Qp	Thv	Dth	Dthv	Dqp
0500	526	380	79.7	6.7	12.1	7.0	13.3	13.6	12.9	-4.2
0530	530	352	80.6	6.8	12.0	7.1	13.3	13.7	12.9	-4.3
0600	534	330	81.4	6.9	12.0	7.1	13.2	13.8	13.0	-4.4
0630	539	312	81.9	7.0	12.0	7.2	13.3	13.8	13.0	-4.4
0700	544	301	82.1	7.1	12.1	7.2	13.3	13.8	13.0	-4.5
0730	549	296	82.1	7.2	12.1	7.2	13.4	13.7	12.9	-4.5
0800	555	297	81.9	7.3	12.2	7.3	13.5	13.6	12.9	-4.5
0830	560	301	81.6	7.4	12.4	7.3	13.6	13.5	12.7	-4.6
0900	566	310	81.1	7.5	12.5	7.3	13.8	13.4	12.6	-4.6
0930	571	320	80.6	7.6	12.7	7.4	14.0	13.3	12.5	-4.7
1000	577	333	80.1	7.7	12.9	7.4	14.1	13.2	12.3	-4.7
1030	582	346	79.5	7.9	13.0	7.4	14.3	13.0	12.2	-4.7
1100	587	359	79.0	8.0	13.2	7.5	14.5	12.9	12.0	-4.8
1130	591	371	78.6	8.1	13.3	7.5	14.7	12.8	11.9	-4.8
1200	596	382	78.2	8.2	13.5	7.5	14.8	12.6	11.8	-4.8
1230	600	392	77.9	8.4	13.6	7.6	14.9	12.5	11.7	-4.9
1300	605	400	77.6	8.5	13.7	7.6	15.1	12.5	11.6	-4.9
1330	609	406	77.5	8.6	13.8	7.6	15.2	12.4	11.5	-5.0
1400	614	410	77.4	8.8	13.9	7.7	15.2	12.3	11.5	-5.0
1430	618	412	77.4	8.9	14.0	7.7	15.3	12.3	11.4	-5.0
1500	623	411	77.5	9.0	14.0	7.7	15.4	12.3	11.4	-5.1
1530	627	409	77.7	9.1	14.0	7.7	15.4	12.3	11.4	-5.1
1600	632	405	78.0	9.3	14.0	7.8	15.4	12.4	11.5	-5.1
1630	638	399	78.3	9.0	14.0	7.8	15.4	12.4	11.5	-5.2
1700	643	392	78.6	8.7	14.0	7.8	15.3	12.5	11.6	-5.2
1730	649	383	79.0	8.4	13.9	7.8	15.3	12.6	11.7	-5.2
1800	655	374	79.4	8.1	13.8	7.8	15.2	12.7	11.8	-5.2
1830	662	366	79.7	7.8	13.8	7.8	15.1	12.8	11.9	-5.2
1900	668	358	79.9	7.5	13.7	7.8	15.1	12.9	12.0	-5.2
1930	675	352	80.1	7.2	13.6	7.8	15.0	13.0	12.1	-5.2
2000	682	348	80.2	6.9	13.6	7.8	14.9	13.1	12.2	-5.2
2030	689	345	80.3	6.6	13.5	7.8	14.9	13.2	12.3	-5.2
2100	696	343	80.4	6.3	13.5	7.7	14.8	13.3	12.4	-5.2
2130	702	341	80.4	6.0	13.4	7.7	14.8	13.4	12.5	-5.1
2200	709	340	80.4	5.7	13.4	7.7	14.8	13.5	12.6	-5.1
2230	715	339	80.4	5.4	13.4	7.7	14.7	13.6	12.7	-5.1
2300	721	339	80.4	5.2	13.3	7.7	14.7	13.6	12.8	-5.1
2330	727	339	80.4	5.2	13.3	7.6	14.6	13.7	12.8	-5.1
0000	733	338	80.5	5.2	13.2	7.6	14.6	13.8	12.9	-5.1
0030	739	338	80.5	5.2	13.2	7.6	14.5	13.9	13.0	-5.1
0100	745	338	80.5	5.2	13.1	7.5	14.5	14.0	13.1	-5.0
0130	751	337	80.5	5.2	13.1	7.6	14.4	14.1	13.2	-5.0
0200	756	337	80.5	5.2	13.1	7.5	14.4	14.1	13.3	-5.0
0230	762	337	80.5	5.2	13.0	7.5	14.4	14.2	13.3	-5.0
0300	767	337	80.5	5.2	13.0	7.5	14.3	14.3	13.4	-5.0
0330	773	307	80.5	5.2	13.0	7.5	14.3	14.3	13.5	-5.0
0400	778	337	80.5	5.2	13.0	7.5	14.3	14.4	13.5	-5.0
0430	783	337	80.5	5.2	12.9	7.5	14.2	14.5	13.6	-5.0
0500	789	337	80.5	5.2	12.9	7.5	14.2	14.5	13.7	-5.0
0530	794	337	80.5	5.2	12.9	7.4	14.2	14.6	13.7	-5.0
0600	799	337	80.4	5.2	12.9	7.4	14.2	14.6	13.8	-5.0
0630	804	338	80.3	5.2	12.9	7.4	14.2	14.7	13.8	-5.0
0700	809	341	80.0	5.2	12.9	7.4	14.2	14.7	13.8	-5.0
0730	814	346	79.7	5.2	12.9	7.4	14.2	14.7	13.8	-5.0
0800	818	354	79.3	5.2	13.0	7.4	14.3	14.7	13.8	-5.0
0830	823	364	78.8	5.2	13.1	7.4	14.4	14.6	13.7	-5.0
0900	827	376	78.2	5.2	13.2	7.4	14.5	14.5	13.7	-5.0
0930	831	390	77.6	5.2	13.3	7.4	14.6	14.5	13.6	-5.0
1000	835	405	76.9	5.2	13.4	7.4	14.7	14.4	13.5	-5.0
1030	838	422	76.3	5.2	13.6	7.4	14.9	14.3	13.4	-5.0
1100	842	439	75.6	5.2	13.7	7.4	15.0	14.2	13.3	-5.0
HOUR	Zi	Zicl	RelHum	WIND	Th	Qp	Thv	Dth	Dthv	Dqp

Fig. B-3. List of Predicted Values-Cloudy Sky



The possibility of a surface based duct (SBD) is indicated and only due to the 'M' value greater at the surface than at the inversion height. Variation in the vertical structure must be emphasized when briefing this forecast in that a SBD may not exist.

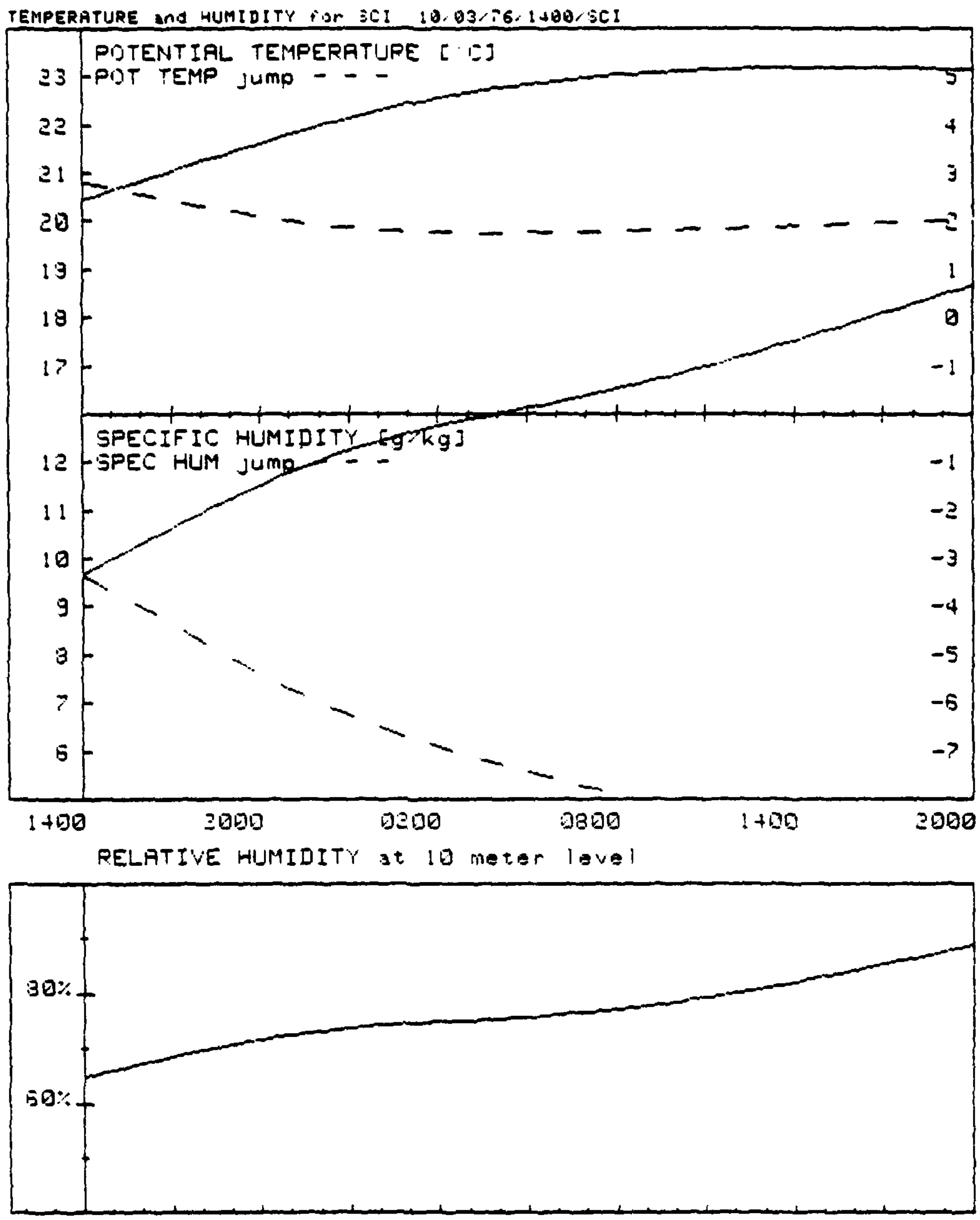
This is a SIMPLIFICATION of the real structure.

This display is divided into UPPER and LOWER windows:

LOWER WINDOW displays the top and middle of the elevated layer and its forecast continued movement for a thirty hour period after beginning. At the bottom is the Relative Humidity at each six hour period. The lightly dotted line is the lifting condensation level. [With enough moisture near the inversion, this can be used as a flag for possible cloud formation, or for high mixed-layer humidity, near the surface, to forecast fog.]

UPPER WINDOW picks out M-value structure (using only 4 points) at each six hour period and will indicate a surface based duct only if the elevated M-value is less than or within 5 of the surface M-value. The sampled times are displayed at top.

Fig. 3-4. Vertical Profile and 'M'' Profiles- Clear Sky



30-HOUR PREDICTION OF POTENTIAL TEMPERATURE AND HUMIDITY
The well-mixed value scale is along the left, the 'jump' value scale is along the right. The third frame is Relative Humidity.

Fig. B-5. Mixed Layer and 'Jump' Values-Clear Sky

This is a list of plotted values. SCI 10/03/76/1400/SCI 15MAR82

HOUR	Zi	Zlcl	RelHum	WIND	Th	Qp	Thv	Dth	Dthv	Dqp
1400	549	806	64.7	5.1	20.4	9.7	22.2	2.8	2.2	-3.3
1430	536	787	65.3	5.3	20.5	9.8	22.3	2.7	2.1	-3.5
1500	524	768	66.0	5.5	20.6	10.0	22.4	2.7	2.0	-3.7
1530	512	750	66.6	5.6	20.7	10.2	22.6	2.6	1.9	-3.9
1600	501	732	67.2	5.8	20.8	10.3	22.7	2.6	1.8	-4.0
1630	491	714	67.9	5.9	20.9	10.5	22.8	2.5	1.7	-4.2
1700	481	697	68.5	6.1	21.0	10.6	22.9	2.4	1.6	-4.4
1730	472	681	69.1	6.2	21.1	10.8	23.1	2.4	1.5	-4.6
1800	463	665	69.6	6.4	21.2	10.9	23.2	2.3	1.5	-4.7
1830	454	650	70.2	6.5	21.3	11.1	23.3	2.3	1.4	-4.9
1900	447	635	70.7	6.7	21.4	11.2	23.4	2.2	1.3	-5.1
1930	439	622	71.2	6.9	21.5	11.4	23.6	2.1	1.2	-5.2
2000	432	609	71.7	7.0	21.6	11.5	23.7	2.1	1.1	-5.4
2030	426	597	72.1	7.2	21.7	11.7	23.8	2.0	1.0	-5.6
2100	420	586	72.5	7.3	21.8	11.8	23.9	2.0	1.0	-5.7
2130	414	575	72.9	7.5	21.9	11.9	24.0	2.0	.9	-5.8
2200	409	566	73.2	7.6	22.0	12.0	24.1	1.9	.8	-6.0
2230	404	558	73.5	7.8	22.1	12.1	24.2	1.9	.8	-6.1
2300	400	550	73.8	7.9	22.1	12.2	24.3	1.9	.7	-6.3
2330	396	544	74.0	8.1	22.2	12.3	24.4	1.8	.7	-6.4
0000	392	538	74.2	8.2	22.3	12.4	24.5	1.8	.6	-6.5
0030	389	533	74.4	8.2	22.4	12.5	24.6	1.8	.6	-6.6
0100	385	528	74.6	8.1	22.4	12.6	24.7	1.8	.6	-6.7
0130	382	524	74.7	8.1	22.5	12.7	24.8	1.8	.5	-6.8
0200	379	521	74.8	8.0	22.6	12.7	24.9	1.8	.5	-6.9
0230	374	518	75.0	7.9	22.6	12.8	24.9	1.8	.5	-7.0
0300	371	515	75.1	7.9	22.7	12.9	25.0	1.8	.5	-7.1
0330	366	511	75.3	7.8	22.7	12.9	25.1	1.7	.5	-7.2
0400	362	508	75.4	7.7	22.8	13.0	25.1	1.7	.4	-7.3
0430	358	504	75.6	7.7	22.8	13.1	25.2	1.8	.4	-7.3
0500	353	500	75.7	7.6	22.9	13.1	25.2	1.8	.4	-7.4
0530	348	496	75.9	7.5	22.9	13.2	25.3	1.8	.4	-7.5
0600	343	491	76.1	7.5	22.9	13.3	25.3	1.8	.4	-7.6
0630	338	486	76.4	7.4	23.0	13.3	25.4	1.8	.4	-7.7
0700	333	480	76.6	7.3	23.0	13.4	25.4	1.8	.4	-7.7
0730	327	474	76.9	7.3	23.0	13.5	25.4	1.8	.4	-7.8
0800	321	467	77.2	7.2	23.0	13.5	25.5	1.8	.4	-7.9
0830	316	460	77.5	7.2	23.1	13.6	25.5	1.8	.3	-8.0
0900	310	453	77.8	7.2	23.1	13.7	25.5	1.8	.3	-8.1
0930	304	445	78.1	7.2	23.1	13.7	25.6	1.8	.3	-8.2
1000	298	436	78.5	7.2	23.1	13.8	25.6	1.8	.3	-8.3
1030	292	427	78.9	7.2	23.1	13.9	25.6	1.8	.3	-8.4
1100	286	417	79.3	7.2	23.1	14.0	25.7	1.8	.3	-8.4
1130	279	407	79.7	7.2	23.2	14.1	25.7	1.8	.3	-8.5
1200	273	397	80.2	7.2	23.2	14.2	25.7	1.9	.3	-8.6
1230	267	386	80.6	7.2	23.2	14.2	25.7	1.9	.3	-8.7
1300	261	374	81.1	7.2	23.2	14.3	25.8	1.9	.3	-8.8
1330	255	363	81.6	7.2	23.2	14.4	25.8	1.9	.3	-8.9
1400	248	351	82.1	7.2	23.2	14.5	25.8	1.9	.3	-9.0
1430	242	338	82.6	7.2	23.2	14.6	25.8	1.9	.3	-9.1
1500	236	326	83.2	7.2	23.2	14.7	25.9	1.9	.3	-9.2
1530	230	313	83.7	7.2	23.2	14.8	25.9	1.9	.2	-9.3
1600	224	300	84.3	7.2	23.2	14.9	25.9	1.9	.2	-9.4
1630	218	287	84.8	7.2	23.2	15.0	25.9	2.0	.2	-9.5
1700	212	274	85.4	7.2	23.2	15.1	25.9	2.0	.2	-9.6
1730	206	260	86.0	7.2	23.2	15.2	25.9	2.0	.2	-9.7
1800	200	247	86.5	7.2	23.2	15.3	25.9	2.0	.2	-9.8
1830	194	234	87.1	7.2	23.2	15.4	26.0	2.0	.2	-9.9
1900	188	221	87.7	7.2	23.2	15.5	26.0	2.0	.2	-10.0
1930	182	207	88.2	7.2	23.2	15.6	26.0	2.0	.2	-10.1
2000	177	195	88.8	7.2	23.2	15.7	26.0	2.0	.2	-10.2
HOUR	Zi	Zlcl	RelHum	WIND	Th	Qp	Thv	Dth	Dthv	Dqp

Fig. 3-6. List of Predicted Values-Clear Sky

APPENDIX C:

TERMS USED IN THE DISCUSSION AND PROGRAM:

Cn2 ... Index of refraction structure function parameter [m -2/3]

Extinction ... loss of EM/EO energy due to absorption/ scattering by species (molecules/aerosols) in the path.

Lifting Condensation Level ... Level at which a parcel will reach saturation if cooled while undergoing lifting.

Mixed Layer ... That part of the boundary layer where turbulent mixing has destroyed the gradients of conservative quantities.

Mixing Ratio ... the ratio of the water-vapor density to the density of the dry air.

Potential Temperature ... the temperature that an air parcel would assume if its pressure were changed by a dry-adiabatic process to some standard pressure.

Relative Humidity ... the ratio of vapor pressure to saturation vapor pressure times 100. Vapor in equilibrium with sea water is assumed to have a relative humidity of 98 per cent.

Specific Humidity ... the ratio of water-vapor density to total density and is usually designated by q.

Subsidence ... a sinking of air from high to low levels. The causes of its occurrence are dynamic, such as the frictional outflow of air near the surface associated

with high-pressure systems, the divergence of air from near the surface high pressure centers, and the divergence of air due to change in latitude as an air mass moves from north to south. (conservation of absolute vorticity)

Thermal wind ... vector wind change with height due to horizontal temperature gradient. This implies advection above the inversion.

Conversion ... KNOTS = (m/s) * 1.94

$$1.94 = \frac{ft}{.3048m} * \frac{Nm}{6076.1ft} * \frac{3600sec}{Hour}$$

```
5  ! **********************************************************
10 ! ***        FOR TIE TO IREPS DATA PREDICTION           ***
15 ! ***   LT DAVID A. BROWER, USN, NPS, MONTEREY, CA.    ***
20 ! **********************************************************
25 ! BASIC DAVIDSON MODEL  'MIXED2'                   MARCH 80
30 ! REVISED CHRIS FAIRALL ENTRAINMENT COMPUTATION  11JAN82
31 ! NOW INCLUDING LONG AND SHORT WAVE RADIATION
     13JAN82
35   EXIT GRAPHICS !                          UPDATED:  19 MAR 82
40   GCLEAR
45   OPTION BASE 1
50   NORMAL
55   OFF ERROR
60   PRINTER IS 0
65   PRINT CHR$(27)&"&132T"
70   PRINTER IS 16
75   Mass$=":T14"    ! CHANGE HERE FOR A NEW MASS STORAGE
80   GOTO 155
85   ! THE FIRST LINE FOR 'COM' NEEDED ONLY FOR 2.0
90 ! COM Irprog$,Irdata$,Rev$,Date$,Prints$,Perforated,
      Date_wanted
95   COM Name$[24],Loc$[24],Time$[24],Type$[1],Height$[1],
        Evap$[1]
100  COM Wmo$(30)[11],Wmont$[5]
105  COM SHORT Presur(30),Temper(30),Relhum(30)
110  COM SHORT Height(30),Munits(30),Nunits(30)
115  COM SHORT Wind,Sea,Air,Relhm,Htzero,Przero,Nmax,Delta,
        Change,Recenv
120  COM SHORT Coml(32,4),Envsq(16),Syssq(32),Lossq(32)
125  COM Envnam$(16)[24],Sysnam$(32)[24],Losnam$(32)[24]
130 ! COM Overlay$[24],Option$[80]
135 ! COM Nrec,Unprotected
140 ! DIM Dummy$[160],Errm$[80]
145 ! DIM Dlabel$[80],Default$[80],Doptions$[80]
150 ! DIM Next_overlay$[24]
155  DIM Windin(10,2),Stick$(3),Frame_loc$[24],Frame_date$[
        24]
160  INTEGER J
165  DIM Pot_temp(30),Spec_hum(30),Zsnd(30),L$[160]
170  Julday=150
175  Lat=33
180  SHORT G(63,7)
185  RESTORE 190
190  READ Z,Zot,Kkk,Alpha_t,Deltim,Stick$(*) ! Alpha t is
        the ratio of heat to
195  DATA 10,5E-5,.35,1.35,1800     !      momentum transfer
        at Psi=0 [from BULK]
200  DATA "Gradient above","Inversion jump","    well-
        mixed"
205  Wsl=Ws=-.003  !TO SET A TYPICAL DEFAULT
210 PRINT PAGE,"THIS IS 'MYREPS' WHICH MODELS THE CHANGE
```

```
        IN THE MIXED LAYER"
215  PRINT TAB(18),"ABOVE THE SURFACE";         !
        REV:18NOV80
220 Start:  Tday$=Date$
225   IF (Tday$="") OR (Tday$=" ") THEN Tday$=" 6MAR82"
230   DISP CHR$(7);"ENTER Today's Date,  THEN press
        'CONT'";
235   INPUT Tday$
240   PRINT Tday$
245   GOSUB Ireps_data
250   ! MINIMUM FREQ TRAPPED IN HERTZ= 3.6033E11*d(-3/2)  d
        DUCT THICKNESS IN m.
255 Option: ! TO WORK WITH THE IREPS KEYS
260 Menu: PRINTER IS 16
265   Aa=0
270   PRINT USING "@,K,2/,K";"This is the DIRECTION MENU",
        "Select option below, ENTER NUMBER and PRESS
        'CONT'."
275   PRINT USING "#,2/,2(10X,K,2/)";"1  COMPUTE NEW
        LAYER(displayed as computed on CRT)","2  PLOT of
        LAYER CHANGES "
280  PRINT USING "3(10X,K,2/),K";"3  END 'MIXED2'
        Program","4  RETURN TO IREPS OPTION LIST PROGRAM (
        with IREPS driver in T15)","5  REVIEW/CHANGE MENU"
285   INPUT "Enter Option(1 to 5) then press CONT",Aa
290   IF NOT ((Aa=1) OR (Aa=2) OR (Aa=3) OR (Aa=4) OR (Aa=5)
        ) THEN Menu
295   IF Aa=4 THEN Menu    !     LOAD "IREPS:T15",Input
        !  PUT IN LATER
300   ON Aa GOTO Start_out,Picture,Bye,Menu,Revchange
        !Subsidence
305   GOTO Menu
310 Start_out: IF Flag_rev THEN Run
315 Start_out_again:  GOSUB Disp_data
320   GOSUB Jullat
325   GOSUB Enter_winds
330   GOSUB Subsidence
335   GOSUB Sea_temp
340   GOSUB Plt_struct
345   GOTO Run
350 Revchange:   PRINTER IS 16    !  TO ENTER ANY CHANGES
        OR REVIEW DATA
355   Rc$="0"
360 IF NOT Flag_data THEN Menu    !  RETURN TO DIRECTION
        MENU IF NO DATA SET
365 Flag_rev=1        ! TO FLAG A RUN THROUGH THE REVISION
        ROUTINE
370   PRINT USING "@,K,/";"This is the REVIEW/CHANGE MENU"
375   PRINT USING "#,/,4(10X,K,2/)";"1  LIST CURRENT
        INITIAL VALUES","2  CHANGE WIND","3  CHANGE
        SUBSIDENCE","4  CHANGE SEA SURFACE TEMPERATURE"
```

```
380 PRINT USING "#,/,3(10X,K,2/)";"5  CHANGE JULIAN DAY
      or LATITUDE","6  REDIGITIZE VERTICAL STRUCTURE","7
      SELECT NEW DATA SET"
385   PRINT USING "10X,K";"8  RETURN TO DIRECTION MENU"
390   INPUT "Enter Option(1 to 8) then press CONT",Rc$
395   PRINT PAGE
400   IF (NUM(Rc$)<49) OR (NUM(Rc$)>56) OR (LEN(Rc$)<>1)
        THEN Revchange
405   IF VAL(Rc$)=7 THEN Start_out_again
410   IF VAL(Rc$)=8 THEN Menu
415   ON VAL(Rc$) GOSUB List_curr,Enter_winds,Subsidence,
        Sea_temp,Jullat,Plt_struct,Disp_data,Menu
420   GOTO Revchange
425 List_curr:    GOSUB Hard_output
430   IF Hd$="Y" THEN PRINTER IS 0
435   PRINT "THESE ARE THE LATEST VALUES FOR THE PREDICTION
        MODEL"
440   PRINT USING "/,K";"DATA SET: "&Loc$&"    "&Time$
445   PRINT USING "/K,X3D,2X9A,M2D,2/,K,M.5D,8X,K,2D";
        "DATE:"&Tday$&"      JULIAN DAY:",Julday,
        "LATITUDE:",Lat,"SUBSIDENCE:",Wsl,"SURFACE TEMP:",
        Sea
450   PRINT USING "/,K,/";"FORECAST WINDS FOR THE PERIOD [
        KNOTS]"
455   FOR Win=1 TO Wn
460   PRINT USING "ZZ,2A,2X,3D.D";Windin(Win,1)/2 MOD 24,
        "00",Windin(Win,2)*1.94
465   NEXT Win
470   IF Hd$="Y" THEN RETURN
475   DISP "PRESS CONT WHEN READY"
480   PAUSE
485   RETURN
490 Jullat:  PRINT USING "@,K,/,K,3D";"FOR DATA SET: "&Loc$&
      "     "&Time$,"CURRENT JULIAN DAY: ",Julday
495   INPUT "ENTER NEW JULIAN DAY(1 TO 366), PRESS CONT
        ",Julday
500   PRINT USING "@,K,M2D.4D";"CURRENT LATITUDE IS :";Lat
505   INPUT "ENTER LATITUDE(DEG  -90 TO 90), PRESS CONT
        ",Lat
510   RETURN
515 Enter_winds: PRINTER IS 16!KNOTS = METERS *1.94 |
      1.94=  ft  *  Nm  *3600sec
520   MAT Windin=ZER          !          SECOND        |
        .3048m 6076.1ft  Hr
525   ON ERROR GOTO 530
530   PRINT USING "@,K, 4X ,K";Loc$,Time$
535   INPUT "ENTER THE BEGINNING TIME ( TO NEAREST HOUR
        e.g. 0600)",In11$
540   IF (LEN(In11$)<>4) OR (VAL(In11$[1;2])>24) THEN 530
545   IF In11$[1;2]="00" THEN In11$[1;2]="24"
550   REDIM G(VAL(In11$[1;2])*2-1:VAL(In11$[1;2])*2+61,7)
```

```
555   OFF ERROR
560   Wn=1
565   Windin(1,1)=Nrl1=VAL(Inl1$[1;2])*2  ! PUT PERIOD IN
         WIND HOLDING ARRAY
570   Q$="Y"
575   Wind_begin1=Wind                     ! USE THE VALUE
         FROM IREPS
580   PRINT USING "@,KX,3D.D,2XK";"WIND FROM  IREPS  IS ";
         Wind*1.94,"KNOTS"
585   INPUT "IS THIS WIND OKAY?  PRESS CONT TO USE THIS
         WIND (Y/N)",Q$
590   IF Q$[1;1]="Y" THEN 610
595   DISP "ENTER BEGINNING WIND SPEED  [KNOTS]  at time ";
         Inl1$;
600   INPUT Wind_begin1
605   Wind_begin1=Wind_begin1/1.94          !CHANGE INTO
         METERS PER SECOND
610   PRINT USING "@,K,4A,K,3D.D,6A";"AT BEGINNING TIME: ";
         Inl1$[1,2]&"00";" THE WIND SPEED IS ";Wind_begin1*
         1.94;" KNOTS"
615   PRINT USING "2/,K,2(/,K)";"Enter the hour and minutes
         of each prediction, then the wind.","Separate time
         from wind by a comma","DISPLAYED winds in KNOTS"
620   PRINT USING "/,K,2Z,16A,/,K";"The last period is 30
         hours after the beginning (i.e. ",(Nrl1/2+30) MOD
         24,"00 the next day)","PERIOD  TIME   WIND"
625   PRINT USING "X2D,5X,4A,5X,2D.D";1,Inl1$[1;4],
         Wind_begin1*1.94
630   G(Nrl1+60,3)=Windin(1,2)=MAX(Wind_begin1,.0001)
635   Q$="Y"
640   FOR Win=2 TO 10   ! MAX OF 10 WIND INPUTS....FIRST
         ONE FROM ABOVE
645 One_wind:  LINPUT "hhmm,WW   FROM THE FORECAST,
      ENTER TIME,WIND(KNOTS) [END when done]",Inl2$
650   IF (Inl2$[1;2]="99") OR (UPC$(Inl2$[1;1])="E") THEN
         Print_wind
655   IF (LEN(Inl2$)<5) OR (Inl2$="") THEN 645
660  IF NOT (Inl2$[5;1]=",") OR (VAL(Inl2$[1;2])>24) OR (
        Inl2$[6;1]="") THEN 645
665   PRINT USING "X2D,5X,4A,5X,K";Win,Inl2$[1;4],Inl2$[6]
670   Windin(Win,1)=VAL(Inl2$[1;2])*2    !  TIMES 2 TO GET
         # OF PERIOD
675   G(Nrl1+60,3)=Windin(Win,2)=MAX(VAL(Inl2$[6])/1.94,
         .0001)
680   IF UPC$(Q$[1,1])="N" THEN RETURN
685   Wn=Win                              ! COUNT THE TOTAL
         WINDS ENTERED
690   NEXT Win
695 Print_wind: Q$="Y" ! HERE TO PUT WIND IN 'G' ARRAY
700   PRINT PAGE,"WINDS THROUGH FORECAST PERIOD"
705   FOR Win=1 TO Wn
```

```
710  PRINT USING "5X,2D,2X,ZZ,2A,2X,3D.D";Win,windin(win,1)/
       2 MOD 24,"00",windin(Win,2)*1.94
715   NEXT Win
720   Q$="Y"
725   INPUT "DO THESE WINDS LOOK OKAY (Y/N)?",Q$
730   IF UPC$(Q$[1,1])="Y" THEN 745
735   IF UPC$(Q$[1,1])="N" THEN Fixwind
740   GOTO Print_wind
745   G(Nr11-1,3)=G(Nr11,3)=windin(1,2)
750   Win1=0
755   Iday1=Nr11
760   FOR Win=2 TO Wn
765   IF Windin(Win,1)<Iday1 THEN Win1=Win1+48
770   G(MIN(windin(Win,1)+Win1,Nr11+61),3)=Windin(Win,2)
        !TO PREVENT TIME BEYOND
775   Iday1=windin(Win,1)
780   G(Nr11+60,3)=Windin(Win,2)  ! AUTOMATIC PUT THE LAST
        WIND INTO END PERIOD
785   NEXT Win
790   RETURN
795 Fixwind:   INPUT "ENTER PERIOD NUMBER TO CHANGE",Win
800   IF Win>Wn THEN Fixwind
805   GOSUB One_wind
810   GOTO Print_wind
815 Subsidence:  ! COME HERE NORMALLY OR FOR RETRY WITH
      DIFFERENT SUBSIDENCE
820   FIXED 4
825   DISP "ENTER  SUBSIDENCE (m/sec) [Prior value=";Ws1;"],
        or CONT to use same value";CHR$(7);
830   INPUT Ws1
835   RETURN
840 Sea_temp:  PRINT "PRESENT VALUE OF SEA SURFACE
      TEMPERATRURE IS ";Sea
845   INPUT "ENTER THE SEA SURFACE TEMP IN ´C or just
        CONT for same value",Sea
850   Tsfc=Sea+273.16
855   RETURN
860 Assig_error:  IF ERRN=80 THEN No_data
865   DISP "ERROR #";ERRN;" in line ";ERRL;"    PRESS
        CONT when ready",CHR$(7)
870   PAUSE
875   GOTO Start
880 No_data:  PRINT PAGE,"DATA FILE NOT AVAILABLE IN LEFT
      TAPE DRIVE.",LIN(2),"EITHER NO TAPE or NOT A DATA
      TAPE.",LIN(2)
885    PRINT "INSERT OR MAKE OTHER CHOICE",LIN(2),"PRESS
         CONT  TO TRY AGAIN WITH DATA TAPE IN LEFT SIDE
         TAPE DRIVE"
890   BEEP
895   PAUSE
900 Ireps_data:    ! TO DISPLAY THE FILE NAMES OF DATA ON
```

```
      IREPS DATA TAPE
905   ON ERROR GOTO Assig_error
910   ASSIGN #5 TO "ENVIR"&Mass$,Ier
915   IF Ier THEN No_data
920   ASSIGN #6 TO "SEQNCE"&Mass$,Ier
925   IF Ier THEN No_data
930   READ #6;Envsq(*),Syssq(*),Lossq(*)
935   ON END #5 GOTO All_out
940     FOR I=1 TO 16
945     READ #5,I;Envnam$(I)
950     NEXT I
955   GOTO All_full
960 All_out:    FOR J=I TO 16    ! I HAS BEEN INCREMENTED 1
      ABOVE LAST READ I
965   Envsq(J)=0
970   NEXT J
975 All_full:  RETURN    !  ARRAY FILLED WITH NAMES and
      REMAINDER WITH 0's


980 Disp_data:  PRINTER IS 16 ! TO PUT THE DATA SETS UP FOR
      CHOICE
985   PRINT USING "@,K,5X,K,2/,5X,2D,2X,K";CHR$(7),
         "EXISTING ENVIRONMENTAL DATA SETS ON IREPS TAPE:",
         0,"NEW or RETURN TO MENU SELECTION"
990   FOR I=1 TO 16
995   Rec=Envsq(I)
1000  IF NOT Rec THEN Pick_data
1005  PRINT USING "5X,DD,2X,K";I,Envnam$(Rec)[1,23]
1010  NEXT I
1015  I=17
1020 Pick_data:   Nrec=I-1
1025   OFF ERROR
1030   IF Nrec<=0 THEN Menu
1035   INPUT "ENTER THE NUMBER OF THE DATA SET DESIRED",
          Dummy
1040   IF Dummy=0 THEN Menu
1045   IF NOT ((Dummy>=1) AND (Dummy<=Nrec)) THEN Disp_data
1050   Rec=Dummy
1055   DISP "PROGRAM IS WORKING RECORD NUMBER ",Rec,";",
          TRIM$(Envnam$(Envsq(Rec))[1,23]),"  IS BEING READ"
1060   READ #5,Envsq(Rec);Name$,Loc$,Time$,Type$,Hight$,
          Evap$,Wmo$(*),Wmoht$
1065   READ #5;Presur(*),Temper(*),Relhum(*),Height(*),
          Munits(*),Nunits(*)
1070   READ #5;Wind,Sea,Air,Relhm,Htzero,Przero,Nmax,Delta,
          Change
1075 FOR I=1 TO Nmax-1
1080  IF (Presur(I)=0) OR (Height(Nmax-I+1)>10000) OR (I=21)
         THEN GOTO 1110
1085      Spec_hum(I)=FNQvalue(Temper(I),Relnum(I))
```

```
1090       Pot_temp(I)=Temper(I)+.0098*Height(Nmax-I)
1095       Zsnd(I)=Height(Nmax-I)*1
1100       Digit_top=I
1105 NEXT I
1110  Press=Przero
1115  IF Press=0 THEN Press=1012  !DEFAULT TO STANDARD IF
         NO OTHER VALUE
1120  MAT G=ZER
1125 Flag_rev=0        ! TO FLAG A NEW DATA SET
1130 Flag_data=1       ! TO FLAG A DATA SET CHOSEN
1135  RETURN             ! GET THE WINDS THEN DO VERTICAL
         STRUCTURE



1140 Plt_struct: !
1145  PLOTTER IS 13,"GRAPHICS"
1150  GRAPHICS                          !**********LABEL
         VERTICAL PLOT**********
1155  PEN 1
1160  LINE TYPE 1
1165  SCALE -3,30,-200,2400
1170  CLIP 0,30,0,2400
1175  AXES 1,500,0,0,5,2
1180  UNCLIP
1185  LORG 2
1190  MOVE -3,-65
1195  LABEL USING "K";"SPEC. HUM.  Q"
1200  MOVE -3,-130
1205  LABEL USING "K";"POT. TEMP.  °C"
1210  LORG 8
1215  MOVE 30,2285                  ! ************DRAW WIND ON
         PLOT*********
1220  LABEL USING "8AX";"FORECAST"
1225  MOVE 30,2225
1230  LABEL USING "K";"TIME   WIND"
1235  FOR L=1 TO Wn
1240  MOVE 30,2200-L*80
1245  BEEP
1250  LABEL USING "ZZ,2A,2X,3D.D";Windin(L,1)/2 MOD 24,"00",
         Windin(L,2)*1.94
1255  NEXT L
1260  LORG 5
1265  FOR L1=1 TO 2
1270 FOR L=5 TO 25 STEP 5
1275  MOVE L,-65*L1
1280       LABEL USING "M3D";L*L1-(L1-1)*10
1285  NEXT L
1290  NEXT L1
1295  FOR L=500 TO 2000 STEP 500      ! ********LABEL SIDE
         NUMBERS*******
```

```
1300  MOVE -1,L
1305  LABEL USING "4D";L
1310  NEXT L
1315  DEG
1320  LDIR 90
1325  LORG 2
1330  MOVE -2.5,0
1335  LABEL USING "K";Loc$&"   "&Time$&"   "&"HEIGHT (meters)
         "&Tday$
1340  LDIR -90
1345  MOVE 3,2400
1350  LABEL USING "XK";"SPECIFIC HUMIDITY Q"
1355  LORG 8
1360  LDIR 90
1365  MOVE 22,2400
1370  LABEL USING "K";"POTENTIAL TEMP  Θ"
1375  MOVE 22,2400
1380  LABEL USING "A";"-"
1385  LDIR 0
1390  LORG 5
1395  MOVE 25,500                    !**********LABEL
         LEGEND**********
1400  LABEL USING "15A";"  √_Q  |Theta_/"
1405  LORG 8
1410  MOVE 30,750
1415  LABEL USING "10A,2X,MZ.4D";"Subsidence",Wsl
1420  MOVE 25,600
1425  LABEL USING "18A";"MIXED LAYER HEIGHT"
1430  FOR L=1 TO 3
1435  MOVE 25,500-L*100
1440  LABEL USING "14A,7X";Stick$(L)
1445  NEXT L
1450  SCALE -16,50,-200,2400
1455  MOVE Pot_temp(1),Height(Nmax)  !**********DRAW THETA *
         *********
1460    FOR L=2 TO MIN(Nmax-1,Digit_top)
1465    DRAW Pot_temp(L),Height(Nmax-L)
1470    NEXT L
1475  Zi=Zi3
1480  POINTER Pot_temp(2),Height(Nmax-3),1   !  FULL SCREEN
         CURSOR
1485  BEEP                           !**********GET THETA***
         *******
1490  DIGITIZE Mixtemp,Zi
1495  MOVE 40,600
1500  LORG 2
1505  LABEL USING "X4D,2A";Zi;"m."
1510  MOVE 40,200
1515  LABEL USING "XM2D.D";Mixtemp
1520  BEEP
1525  POINTER Mixtemp+5,Zi,2
```

```
1530  DIGITIZE Top_inv_temp,Mmm
1535  MOVE 40,300
1540  LABEL USING "X2D.D";Top_inv_temp-Mixtemp
1545  POINTER Top_inv_temp+10,2350,2
1550  BEEP
1555  DIGITIZE Top_temp,Top_temp_alt
1560  MOVE 40,400
1565  LABEL USING "XZ.4D";(Top_temp-Top_inv_temp)/(
         Top_temp_alt-Zi) !


1570  LINE TYPE 3          !***********DRAW STICK THETA********
         **
1575   MOVE Mixtemp,0
1580   DRAW Mixtemp,Zi
1585   DRAW Top_inv_temp,Zi
1590   DRAW Top_temp,Top_temp_alt
1595  LINE TYPE 1
1600   LORG 8  !WRITE UNDER 'Q' SIDE
1605  SCALE -3,30,-200,2400
1610   BEEP
1615  LINE TYPE 8
1620    MOVE Spec_hum(1),Height(Nmax) !**********DRAW Q ****
          ******
1625    FOR L=2 TO MIN(Nmax-1,Digit_top)
1630    DRAW Spec_hum(L),Height(Nmax-L)
1635    NEXT L
1640    LINE TYPE 1
1645   POINTER Spec_hum(2),Zi,1
1650  DIGITIZE Mixq,Mmm     ! USING THIS TERM SO SCALE STAYS
         THE SAME
1655   MOVE 25,200
1660   LABEL USING "M2D.2DX";Mixq
1665   POINTER Mixq/2,Zi,2
1670   BEEP
1675   DIGITIZE Top_inv_q,Mmm   ! USE FOR SAME SCALE FACTOR
          GRAPHICS
1680   MOVE 25,300
1685   LABEL USING "M2D.2DX";Top_inv_q-Mixq
1690   POINTER Top_inv_q/2,2350,2
1695   BEEP
1700   DIGITIZE Top_q,Top_q_alt
1705   MOVE 25,400
1710   LABEL USING "M.4DX";(Top_q-Top_inv_q)/(Top_q_alt-Zi)
1715   Zi3=Zi
1720   LINE TYPE 4          !**********DRAW STICK Q *******
          ***
1725   MOVE Mixq,0
1730   DRAW Mixq,Zi
1735   DRAW Top_inv_q,Zi
```

```
1740   DRAW Top_q,Top_q_alt
1745   LINE TYPE 1
1750  SCALE -16,50,-200,2400
1755   MOVE 40,100
1760   LORG 5 !**********  FOR DECISION OF A GOOD FIT OR
          NOT**********
1765   LABEL USING "17A";" OKAY <-|-> AGAIN"
1770   POINTER 40,100,2
1775   BEEP
1780   DIGITIZE D,Mmm
1785   IF D=40 THEN 1770
1790   IF D>40 THEN Plt_struct
1795   PRINTER IS 16
1800   PRINT PAGE
1805   MOVE 40,100
1810   DISP "CLEARING PICTURE"
1815   EXIT GRAPHICS
1820      PEN -1
1825   LABEL USING "17A";" OKAY <-|-> AGAIN"
1830   GOSUB Hard_output
1835   IF Hd$="N" THEN 1885
1840  PRINTER IS 0
1845 PRINT USING "  1X,K,2(6X,K),/";"ENVIRON. DATA LIST,
        FROM MIXED2",Loc$,Time$
1850 PRINT USING "3(10A,X4D.D,9X18A,M3D.D,/)";"WIND",Wind,
        "AIR TEMP",Air,"SEA TEMP",Sea,"REL HUM",Relhm,"SFC
        PRESS",Przero,"IREPS EVAP DUCT HT",Delta
1855  PRINT "LEVEL  PRESS   TEMP  RH %   METERS  M UNITS
         POTENT TEMP  SPEC HUM"
1860 FOR I=1 TO MIN(18,Digit_top)
1865 PRINT USING "3D,3X,4D.D,2X,M2D.D,X,3D.D,X,6D.D,4X,4D,2(
        6X,M3D.D)";I,Presur(I),Temper(I),Relhum(I),Height(
        Nmax-I),Munits(Nmax-I),Pot_temp(I),Spec_hum(I)
1870 NEXT I
1875  DUMP GRAPHICS
1880  PRINT USING "@"
1885  PRINTER IS 16
1890  EXIT GRAPHICS
1895  RETURN
1900 Run:  T10=Mixtemp   !**********PREP DATA FOR RUN WITH
        IREPS**********
1905        Zi=Zi3
1910  Qp=Mixq
1915  Dqp=Top_inv_q-Mixq
1920  Dqdzu=(Top_q-Top_inv_q)/(Top_q_alt-Zi)
1925  Dth=Top_inv_temp-Mixtemp
1930  Dtdzu=(Top_temp-Top_inv_temp)/(Top_temp_alt-Zi)
1935  Ws=Wsl
1940  Frame_loc$=Loc$
1945  Frame_date$=Time$
1950  EXIT GRAPHICS
```

```
1955    CALL Sky2(Zi,Nmax*1,Pot_temp(*),Zsnd(*),Spec_hum(*),
          Tsky,Ftop)
1960  Mhr=60              !  TO SET MHR= NUMBER OF HALF HOUR
          PERIODS
1965  OFF ERROR
1970 PRINT PAGE,TAB(9),"THIS IS 'MIXED2', MODELING THE
        CHANGE IN THE MIXED LAYER"
1975 PRINT TAB(10),"ABOVE THE OCEAN SURFACE. Today is "&
        Tday$
1980  Numhr=Nrll+Mhr
1985  PRINTER IS 16
1990  PRINT USING "/,15X,K,/,20X,4Z,2XK,/19X,4D,K,/";"DATA
         PARAMETERS CHOSEN",Nrll/2 MOD 24*100,"BEGINNING
         TIME",Zi,"m  CAPPING INVERSION HEIGHT"
1995  Vdt=0
2000 ! INPUT "ENTER A VALUE FOR 'Vdte' ('C/12hr) , or PRESS
        CONT FOR DEFAULT TO 0  ?",Vdt
2005  Vdte=Vdt/24
2010 ! PRINT "THE VALUE FOR 'Vdte' IS ";Vdt;"'C/12hr   or ";
        Vdte;" 'C per TIME STEP"
2015  Th=T10+273.16
2020  J=Nrll-1
2025  G(Nrll-1,1)=Zi
2030  GOSUB Bulk
2035  Nrl=Nrll
2040  I=Nrl                    ! FIND FIRST INPUT DATA LINE
2045  I=I+1                    ! INCREMENT TO NEXT LINE
2050   IF G(I,3)=0 THEN 2045! IF NO DATA, INCREMENT
2055  Nd=I-Nrl                 ! FIGURE TIME SPREAD
2060     X5=(G(I,3)-G(Nrl,3))/Nd  !U10
2065  FOR J=1 TO Nd-1          ! STEP THROUGH EMPTY POINTS
2070     G(J+Nrl,3)=G(Nrl,3)+X5*J
2075  NEXT J                              ! DQDZU= Specific hum
         gradient above inv.
2080  Nrl=I                               ! DTH= Potential
         temperature jump
2085  IF I<Numhr THEN 2045                ! DTDZU= Temp
         gradient above inversion
2090     T=Th-.0098*Zi*.5-273.16          ! DQW= Specific
            humidity jump
2095     Lcp=(596.73-.601*L)/.24          ! TH= Well mixed
            potential temperature
2100     Tt=T-.0098*Zi*.5+273.16          ! Qp= Well mixed
            specific humidity
2105     Te=Th*(1+Lcp/Tt*Qp/1000)         ! ZI= Inversion height
2110     Dte=Dth+Th/Tt*Lcp*Dqp/1000       ! DELTIM=Time step
            between solutions
2115     Dtedzu=Dtdzu+Th/Tt*Lcp*Dqdzu/1000
2120     Dqw=Dqp/1000
2125     Qw=Qp/1000
2130     Aws=Ws/Zi               ! AVERAGE Ws THRU THE MIXED
```

```
          LAYER
2135     Zws=Zi                    ! REMEMBER HEIGHT OF
          BEGINNING Ws
2140 PLOTTER IS 13,"GRAPHICS"
2145 SCALE Nr11-20,Nr11+80,-100,2000
2150 CLIP Nr11,Nr11+61,0,1200
2155 AXES 4,200,Nr11,0,3,5
2160 FRAME
2165 GRAPHICS  !




2170   Run$="*"
2175 Looper:  FOR J=Nr11 TO Nr11+Mhr
2180   Zi1=Zi           ! HOLD ONTO PREVIOUS HEIGHT
2185   PLOT J,Zi        ! FOR THE QUICK PLOT
2190  T10=Th-273.16     ! T10 CARRIED BACK FROM 'Bulk' AS Th
2195     Q10=Qp         ! NEW VALUE OF Qp
2200   FIXED 2
2205   Dtedzu=Dtdzu+Th/Tt*Lcp*Dqdzu/1000
2210   IF J>Nr11+56 THEN Run$="!"
2215      DISP "PERIOD BEGIN:";TAB(14+(J-Nr11)/2);Run$;TAB(
            45);":END    Layer at";G(J-1,1)
2220  O2=Dqdzu/1000                      ! TO CHANGE G/KG TO G/
        G
2225  Timesec=J*1800
2230  CALL Zenith(Timesec,Julday,Lat,Theta)
2235 CALL M2(T10,Q10,Zlcl,Zi,Ustar,Tstar,Qstar,Tstv,Ws,Delr,
       O2,Dte,Dqw,Dhdt,Ddtedt,Ddqwdt,Dtedt,Dqwdt,Wtv,
       Dtedzu,Tsfc,Theta,Tsky)
2240  G(J,2)=Zlcl
2245  G(J,1)=Zi=Zi+Dhdt*Deltim
2250    Qw=Qw+Dqwdt*Deltim          ! GRAMS PER GRAM
2255  G(J,4)=Q10=Qp=Qw*1000         ! GRAMS PER KILOGRAM
2260    Te=Te+Dtedt*Deltim          ! EQUIVALENT POTENTIAL
          TEMP
2265    Dqw=Dqw+Ddqwdt*Deltim       ! GRAMS PER GRAM
2270  G(J,6)=Dqp=Dqw*1000           ! GRAMS PER KILOGRAM
2275    Dte=Dte+Ddtedt*Deltim+Vdte  ! ADDING THERMAL WIND
2280    Ws=Aws*Zi                   ! RESETTING LAYER
          SUBSIDENCE
2285    Zws=Zws+Aws*Zws*Deltim
2290    Tt=Tt-.0098*(Zi-Zi1)        ! Tt IN KELVIN
2295    T=Tt+.0098*Zi*.5-273.2
2300    Lcp=(596.73-.601*T)/.24
2305  G(J,5)=Th=Te/(1+Lcp*Qw/Tt)   ! Th in KELVIN
2310  G(J,7)=Dth=Dte-Th/Tt*Lcp*Dqw
2315 ! G(J,2)=MIN(100,FNRelhum(Qp,Th))     ! FIGURED AT 10
       METER LEVEL
```

```
2320     GOSUB Bulk  ! COMPUTE STAR VALUES FOR NEXT TIME
            PERIOD

2325     NEXT J
2330     EXIT GRAPHICS
2335     GOTO Menu  !


2340 Bulk: ! TO COMPUTE THE NEXT SET OF VALUES FOR U*,T*,Q*,
          T*v
2345    U10=MAX(.2,G(J,3)) ! WIND CHANGES THROUGH THE PERIOD
2350    IF U10>=2.2 THEN Cdn=.789*U10^.259/1000 ! FIGURE
           DRAG FROM WIND CURVE FIT
2355    IF U10<2.2 THEN Cdn=U10^(-.15)*1.08/1000  ![ DAB
           SEP 80]
2360    RAD
2365    Tdelta=Th-Tsfc    ! DIFFERNCE IN TEMPERATURE AND Q-
           value
2370    Qdelta=Qp-FNQvalue(Sea,98) ! FROM 10meters TO THE
           SURFACE
2375    Zo=Z*EXP(-Kkk/SQR(Cdn))
2380    Ctn_sqrt=Alpha_t*Kkk/LOG(Z/Zot)
2385    S1=S=So=Kkk*9.8*Z/Th*(Ctn_sqrt/Cdn)*(Tdelta+.00061*
           Th*Qdelta)/U10^2
2390      IF So<0 THEN 2450
2395      IF So<2 THEN GOTO 2420
2400         S=10
2405         Psi1=-47
2410         Psi2=-64
2415        GOTO Stars
2420         Psi1=-S*4.7
2425         Psi2=-S*6.4
2430      S=So*Alpha_t/Kkk*((Kkk-SQR(Cdn)*Psi1)^2/(Alpha_t*
             Kkk-Ctn_sqrt*Psi2))
2435   IF ABS(S-S1)<.001 THEN Stars
2440      S1=S
2445   GOTO 2420
2450         X1=(1-15*S)^.25
2455         X2=(1-9*S)^.5
2460         Psi2=2*LOG((1+X2)/2)
2465         Psi1=2*LOG((1+X1)/2)+LOG((1+X1^2)/2)-2*ATN(X1)+
                PI/2
2470      S=So*Alpha_t/Kkk*((Kkk-SQR(Cdn)*Psi1)^2/(Alpha_t*
             Kkk-Ctn_sqrt*Psi2))
2475   IF ABS(S-S1)<.001 THEN Stars
2480      S1=S
2485   GOTO 2450
2490 Stars:    Mult=Alpha_t*Kkk/(LOG(Z/Zot)-Psi2)
2495           Ustar=Kkk*U10/(LOG(Z/Zo)-Psi1)
2500           Tstar=Tdelta*Mult
2505           Qstar=Qdelta*Mult
```

```
2510           Tstv=Tstar+.61*Qstar*Th/1000
2515  RETURN ! VALUES BACK FOR BEGINNING AND FOR DURING
        RUN


2520 Picture: EXIT GRAPHICS
2525  IF NOT Flag_data THEN Menu
2530    PRINTER IS 16
2535    OFF ERROR
2540    PRINT USING "@,K,2/,3(10X,K,2/)";"TYPE OF PLOT:","1
          PLOT THE 'BIG PICTURE'","2  PLOT OF 'Q', 'THETA'
          AND JUMPS","3  LIST OF THE PLOTTED VALUES"
2545    PRINT "              4  RETURN TO DIRECTION MENU"
2550    ON ERROR GOTO Picture
2555    INPUT "ENTER MODE of output?",Vss
2560    PRINT PAGE,"PRESS  CONT wnen picture is done",LIN(
          2),"    [ k3  TO DISPLAY GRAPHICS]"
2565    IF Vss=1 THEN CALL Frame(G(*),Nr11,Tday$,Dqdzu,
          Dtdzu,Press,Frame_loc$,Frame_date$,Mhr)
2570    ON Vss GOTO Picture,Mix_plot,Gval,Menu
2575 !  ON Vss GOTO Picture,Picture,Gval,Menu
2580    GOTO Picture
2585 Hard_output: Hd$="N"
2590    INPUT "DO YOU WANT HARD COPY OUTPUT (N/Y)",Hd$
2595    Hd$=UPC$(Hd$[1,1])
2600    IF (Hd$="Y") OR (Hd$="N") THEN RETURN
2605    GOTO Hard_output !


2610 Gval:! PRINT OUT THE VALUES FOR THE ENTIRE PERIOD
2615  GOSUB Hard_output
2620  OFF ERROR
2625    IF Hd$="Y" THEN PRINTER IS 0
2630 L$="This is a list of plotted values. "&Loc$&"    "&
        Time$&"  "&Tday$
2635   PRINT L$[1;78],LIN(1)
2640 PRINT "HOUR    Zi    Zlcl RelHum  WIND    Th      Qp
        Thv      Dth    Dtnv    Dqp"
2645    FOR G1=Nr11 TO Nr11+Mhr
2650    G2=INT(G1 MOD 48/2)*100+FRACT(G1 MOD 48/2)*60
2655  G3=G(G1,5)*(1+.00061*G(G1,4))! Thv
2660  G4=G(G1,7)+.00061*G(G1,5)*G(G1,6)! Dthv
2665  G5=FNRelhum((G(G1,4)),(G(G1,5)))
2670    PRINT USING "4Z2X,2(4DX),2(M3D.DX),6(3D.D2X)";G2,G(
          G1,1),G(G1,2),G5,G(G1,3),G(G1,5)-273.16,G(G1,4),
          G3-273.16,G(G1,7),G4,G(G1,6)
2675    NEXT G1
2680    PRINT "HOUR    Zi    Zlcl RelHum  WIND    Th      Qp
          Thv      Dth    Dtnv    Dqp"
2685    DISP "PAUSING FOR 2 SECONDS THEN RETURNING TO THE
          START"
```

```
2690  IF Hd$="N" THEN WAIT 2000
2695    ! WHEN YOU ARE READY, JUST PRESS CONT
2700    PRINT PAGE
2705    GOTO Picture!


2710 Mix_plot:! BEGIN PLOT OF Qp,Dqp,Th,Dth,RH
2715   OFF ERROR
2720   PLOTTER IS 13,"GRAPHICS"
2725   GRAPHICS
2730   FRAME
2735   SCALE Nrll-5,Nrll+60,-8,8
2740   CLIP Nrll,Nrll+60,-8,8
2745   AXES 2,1,Nrll,0,3,1
2750   LORG 2
2755   MOVE Nrll,7.5
2760   LABEL USING "K";" POTENTIAL TEMPERATURE [´C]"
2765   MOVE Nrll,7
2770   LABEL USING "K";" POT TEMP jump - - -"
2775   MOVE Nrll,-.5
2780   LABEL USING "K";" SPECIFIC HUMIDITY [g/kg]"
2785   MOVE Nrll,-1
2790   LABEL USING "K";" SPEC HUM jump - - -"
2795   FOR K=0 TO 2 STEP 2
2800       LORG 8
2805    SCALE Nrll-5,Nrll+60,INT(G(Nrll,4+K))-4,INT(G(Nrll,
           4+K))+12
2810    FOR I=0 TO 1
2815     P=-2
2820     LINE TYPE 1
2825     FOR L=INT(G(Nrll,4+K+I)-3-273.16*((K=0) AND (I=1)))
            TO INT(G(Nrll,4+K+I)+3-273.16*((K=0) AND (I=1)))
2830       MOVE Nrll+K*30,L
2835       LABEL USING "MDDX";L
2840     NEXT L
2845     LINE TYPE 1+3*(K=2)
2850     FOR J=Nrll TO Nrll+60
2855     PLOT J,G(J,4+I+K)-((I=1) AND (K=0))*273.16,P
2860     P=-1
2865     NEXT J
2870    SCALE Nrll-5,Nrll+60,INT(G(Nrll,5+K)-12-273.16*(K=0)
           ),INT(G(Nrll,5+K)+4-273.16*(K=0))
2875    NEXT I
2880   LINE TYPE 4
2885   NEXT K
2890   GOSUB Hard_output
2895   IF Hd$="Y" THEN PRINTER IS 0
2900   PRINT USING "K";"TEMPERATURE and HUMIDITY for "&Loc$&
         "  "&Time$
2905   IF Hd$="Y" THEN DUMP GRAPHICS
2910   GCLEAR
```

AD-A115 769 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 4/2
MARINE ATMOSPHERIC BOUNDARY LAYER AND INVERSION FORECAST MODEL.(U)
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```
2915   SCALE Nr11-5,Nr11+60,-20,120
2920   LINE TYPE 1
2925   CLIP Nr11-5,Nr11+60,40,100
2930   FRAME
2935   AXES 2,10,Nr11,40,3,2
2940   MOVE Nr11,FNRelhum((G(Nr11,4)),(G(Nr11,5)))
2945   FOR I=Nr11+1 TO Nr11+60
2950   DRAW I,FNRelhum((G(I,4)),(G(I,5)))
2955   NEXT I
2960   LORG 2
2965   MOVE Nr11,105
2970   LABEL USING "K";" RELATIVE HUMIDITY at 10 meter
          level"
2975   LORG 7
2980   MOVE Nr11,80
2985   LABEL USING "3AX";"80%"
2990   MOVE Nr11,60
2995   LABEL USING "3AX";"60%"
3000   FOR Cc=Nr11 TO Nr11+60 STEP 12
3005   MOVE Cc,110
3010   LABEL USING "ZZ,ZZ";INT(Cc/2) MOD 24,FRACT(Cc/2)*60
3015   NEXT Cc
3020  IF Hd$="Y" THEN DUMP GRAPHICS 40,115
3025   BEEP
3030   IF Hd$="N" THEN PAUSE
3035  EXIT GRAPHICS
3040   IF Hd$="N" THEN Picture
3045   PRINTER IS 0
3050   PRINT USING "2(/,9XK)";"30-HOUR PREDICTION OF
          POTENTIAL TEMPERATURE AND HUMIDITY","The well-
          mixed value scale is along the left, the 'jump'
          value"
3055   PRINT USING "8XK,@";"scale is along the right.  The
          third frame is Relative Humidity."
3060   GOTO Picture!


3065 Bye:  PRINT PAGE,"THIS PROGRAM IS ENDING AND REWINDING
          THE TAPE"
3070  PRINT LIN(1),"REMOVE TAPE BY PRESSING THE EJECT BAR"
3075  ON ERROR GOTO 3085
3080  REWIND ":T15"
3085  ON ERROR GOTO 3095
3090  REWIND ":T14"
3095  PRINT LIN(6),TAB(36),"Good bye"
3100  BEEP
3105  OFF ERROR
3110 En:  END!
```

```
3115 SUB M2(T10,Q10,Zlcl,Zi,Ust,Tst,Qst,Tstv,Ws,Delr,Dqdzu,
        Dte,Dqw,Dhdt,Ddtedt,Ddqwdt,Dtedt,Dqwdt,Wtv,Dtedzu,
        Tsfc,Theta,Tsky)
3120   Tt=T10+273.2-.0098*Zi/2
3125  Thet=(Tt+Zi*.0098)/Tt
3130  Cl=(596.73-.601*(Tt-273.2))/(.24*Tt)   ! Cl=L/(Cp*T)
3135  Wt=-Tst*Ust
3140  Wtv=-Tstv*Ust
3145  Wq=-Qst*Ust/1000
3150  Wte=Wt+Thet*Cl*Tt*Wq
3155  Te=T10+2.43*Q10
3160 CALL Parcel0(Te,Q10,Zi,Rh,Thr,Qv,Ql,Zlcl)
3165  Qs=Qv/1000*Rh/100
3170  Qliq=Ql/1000
3175  ! WAIT 1000
3180 CALL We2(Zi,Zlcl,Dte,Dqw,Qs,Thr,Qliq,T10,Tsfc,Ust,Tst,
        Qst,Tstv,We2,Delr,Tsky)     ! NEED TO CALL PARCEL
        FIRST
3185  CALL Shrtwv(Theta,Ql,Zlcl,Zi,Q10,Dtemp)
3190  We=We2
3195  Dhdt=We+Ws     ! Rate of change of mixed layer depth,
        Ws is subsidence
3200  Ddtedt=Dtedzu*We+(-We*Dte-Wte+Thet*Delr)/Zi-Dtemp
3205  Ddqwdt=Dqdzu*We+(-We*Dqw-Wq)/Zi
3210  Dtedt=(Wte-Thet*Delr+We*Dte)/Zi+Dtemp
3215  Dqwdt=(Wq+We*Dqw)/Zi
3220  SUBEND  ! END OF 'M2' SUBPROGRAM



3225  DEF FNQvalue(SHORT Tx,R)   !FIGURE THE 'Q' VALUE
        GIVEN:
3230  Qvb=.053542*EXP(-5399.286*(1/(Tx+273.16)-3.5905E-3))*R
3235  RETURN Qvb !TAKE THE Q value BACK
3240  FNEND!


3245 Frame:SUB Frame(SHORT G(*),REAL Nrll,Tday$,Dqdzu,Dtdzu,
        Press,Frame_loc$,Frame_date$,Mhr)
3250  OPTION BASE 1
3255  DIM Zg(4)
3260   PLOTTER IS 13,"GRAPHICS"
3265   GRAPHICS
3270 SCALE Nrll-6,Nrll+60,-200,2400
3275 CLIP Nrll,Nrll+60,0,2400
3280 AXES 2,100,Nrll,0,6,2,3
3285 MOVE Nrll+26,-110
3290 LORG 5
3295 DEG
3300 LABEL USING "K";"Atmospheric Mixed Layer Movement 30
        Hours "&Tday$
```

```
3305 MOVE Nrll+26,-170
3310 LABEL USING "K";Frame_loc$&"   "&Frame_date$&"  LT D.
        BROWER  NPS"
3315 LDIR 90
3320     MOVE Nrll-4.5,600
3325     LABEL USING "K";"Mixed Layer(meters)"
3330     MOVE Nrll-4.5,1800
3335     LABEL USING "K";"DUCT HEIGHT (meters)"
3340 CSIZE 2.7,.6
3345 LDIR 0
3350  MOVE Nrll+30,1050
3355  LABEL USING "K";"Vertical Profile 'M-value' (every
         SIX hours)"
3360   FOR Cc=Nrll TO Nrll+Mhr STEP 12
3365   MOVE Cc,-30   !Print out time at bottom
3370   Bb=INT(Cc/2)
3375   Bbb=FRACT(Cc/2)*60
3380   Bb=Bb MOD 24
3385   LABEL USING "ZZ,ZZ";Bb,Bbb
3390   Bb=(Bb+3) MOD 24
3395   MOVE Cc+6,2370 ! PRINT OUT TIME AT TOP
3400   LABEL USING "ZZ,ZZ";Bb,Bbb
3405   NEXT Cc
3410   FOR Cv=1 TO 5  ! Label side
3415   MOVE Nrll-2,Cv*200
3420   LABEL USING "4D";Cv*200
3425   NEXT Cv
3430 MOVE Nrll,G(Nrll,1)
3435  GRAPHICS
3440  FOR V=Nrll+1 TO Nrll+Mnr! Draw out the max 'M' height
         at the inversion
3445   DRAW V,G(V,1)
3450   NEXT V
3455   LINE TYPE 4
3460 MOVE Nrll,G(Nrll,1)*1.1
3465  FOR V=Nrll+1 TO Nrll+Mhr!Draw out the min 'M' height
         above the inversion
3470   DRAW V,G(V,1)*1.1
3475   NEXT V
3480   LINE TYPE 2
3485   MOVE Nrll,G(Nrll,2)
3490   FOR V=Nrll+1 TO Nrll+Mnr! DRAW THE LIFTING
          CONDENSATION LEVEL
3495   DRAW V,G(V,2)
3500   NEXT V
3505   LINE TYPE 1!


3510 Profile:! COMPUTES AND PLOTS PREDICTED PROFILES
3515  SCALE -1.5,15,-1400,1200  ! Draw vertical lines in
         lower window
```

```
3520  LINE TYPE 3
3525   FOR D=1.5 TO 13.5 STEP 3
3530   MOVE D,-1200
3535   DRAW D,0
3540   NEXT D
3545   LINE TYPE 1     !Get set for upper window
3550  CLIP 0,15,-1200,1200
3555  AXES 1,100,15,0,3,2,7
3560  GRAPHICS
3565  Sbd=0  ! FLAG FOR SURFACE BASED DUCT WARNING TO PRINT
         OUT
3570  CSIZE 2.7,.6
3575     FOR Cv=1 TO 5    ! label left side
3580     MOVE -.5,Cv*200
3585     LABEL USING "4D";Cv*200
3590     NEXT Cv
3595   Zg(1)=0
3600   Zg(4)=1200  !


3605   FOR Pr=0 TO 4
3610   Pm=Pr*150
3615   Hrg=Nr11+6+12*Pr        ! Pull out hours for profiles
3620   FOR I=1 TO 4        ! Determine multiples to use for
          altitude
3625   Zg(2)=G(Hrg,1)
3630   Zg(3)=G(Hrg,1)*1.1  ! TO SET INVERSION THICKNESS =.1*
          HEIGHT
3635   ! COMPUTES Q AND THETA
3640   Pp1=G(Hrg,4)+(I>=3)*G(Hrg,6)+(I=4)*Dqdzu*(1200-Zg(3))
3645   Pp2=G(Hrg,5)+(I>=3)*G(Hrg,7)+(I=4)*Dtdzu*(1200-Zg(3))
3650   ! COMPUTES PRESSURE ,VAPOR PRESSURE AND TEMP(K)
3655   P=Press-.120*Zg(I)
3660   E=P*Pp1/622
3665   T=Pp2-.0098*Zg(I)
3670   ! COMPUTES MODIFIED INDEX OF REFRACTION
3675   Pp(I)=77.6*P/T+373000*E/(T*T)+.157*Zg(I)
3680   NEXT I
3685   LORG 5 !Label bottom of 'M' profile
3690   SCALE 225,1050,-1400,1200
3695   MOVE Pm+375,-80
3700   LABEL USING "K";"350  400"
3705   MOVE Pp(1)+Pm,Zg(1)          ! Draw each profile
3710   FOR I=2 TO 4
3715   DRAW Pp(I)+Pm,Zg(I)
3720   NEXT I
3725   IF (Pp(3)<Pp(1)) OR (ABS(Pp(3)-Pp(1))<5) THEN GOSUB
          Sfc_duct
3730   LINE TYPE 3
3735   MOVE Pp(3)+Pm,Zg(3)
3740   DRAW Pp(3)+Pm,MAX(0,(Pp(3)-Pp(1))/(Pp(2)-Pp(1))*Zg(2)
```

```
        )
3745   LINE TYPE 1
3750   MOVE 375+Pm,-1150                   ! MOVE TO EACH SIX
          HOUR SPOT
3755   A=FNRelhum((G(Hrg,4)),(G(Hrg,5)))
3760   LABEL USING "3D.D";A
3765   NEXT Pr
3770   BEEP
3775   PAUSE
3780   EXIT GRAPHICS
3785   Hd$="N"
3790   INPUT "DO YOU WANT HARD COPY OUTPUT (N/Y)",Hd$
3795   IF Hd$[1,1]="N" THEN SUBEXIT
3800   PRINTER IS 0
3805   PRINT LIN(2)
3810   DUMP GRAPHICS
3815   IF NOT Sbd THEN 3840
3820  PRINT LIN(2),"    The possibility of a surface
         based duct(SBD) is indicated and only"
3825  PRINT "due to the 'M' value greater at the surface
         than at the inversion"
3830  PRINT "height.  Variation in the vertical structure
         must be emphasized"
3835  PRINT "when briefing this forecast in that a SBD may
         not exist."
3840  PRINT LIN(1),"   This is a SIMPLIFICATION of the real
         structure."
3845  PRINT LIN(1),"   This display is divided into UPPER
         and LOWER windows:"
3850  PRINT "LOWER WINDOW displays the top and middle
         of the elevated layer and its"
3855  PRINT "   forecast continued movement for a thirty
         hour period after beginning."
3860  PRINT "   At the bottom is the Relative Humidity at
         each six hour period."
3865  PRINT "   The lightly dotted line is the lifting
         condensation level."
3870  PRINT "       [with enough moisture near the inversion,
         this can be used"
3875  PRINT "       as a flag for possible cloud formation,
         or for high mixed-"
3880  PRINT "       layer humidity, near the surface, to
         forecast fog.]"
3885  PRINT "UPPER WINDOW picks out M-value structure (
         using only 4 points)"
3890  PRINT "   at each six hour period and will indicate a
         surface based duct"
3895  PRINT "   only if the elevated M-value is less than
         or within 5 of"
3900  PRINT "   the surface M-value.  The sampled times are
         displayed at top."
```

```
3905  PRINT PAGE
3910  SUBEXIT
3915 Sfc_duct:  LORG 1
3920  BEEP
3925  LDIR 90
3930  MOVE Pp(3)+Pm-5,Zg(3)+20
3935  LABEL USING "K";"Surface Duct"
3940  Sbd=1
3945  LDIR 0
3950  LORG 5
3955  RETURN
3960 SUBEND!


3965  DEF FNRelhum(Q,T)
3970  T1=T-.0098*10
3975  C=23.84-2948/T1-5.03*LGT(T1)
3980  P=1012-.120*10
3985  Relhum=MIN(100,Q*100/(625*10^C/P))
3990  RETURN Relnum
3995  SUBEND!


4000  SUB We2(Zi,Zlcl,Dte,Dqw,Qs,Thr1,Qliq,Th1,Tsfc,Ust,Tst,
         Qst,Tstv,We2,Delr2,Tsky) ! NEED TO CALL PARCEL
         FIRST
4005  Dth=Dte-2500*Dqw
4010  Thr=Thr1+273.16
4015  Th=Th1+273.16
4020  Epsilon=.622 !RATIO OF WATER AND AIR
4025  Sigma=4.61E-11 ! STEFANS CONSTANT RELATING TEMP TO
         BLACK BODY RADIATION
4030  W1=Qliq*1250
4035  Emiss=MAX(0,1-EXP(-(Zi-Zlcl)*.138*W1/2))! EMISSIVITY
4040  Tc=Th-.0098*Zlcl  ! TEMP AT BOTTOM OF CLOUD
4045  Tb=Thr-.0098*Zi   ! TEMP AT TOP OF CLOUD
4050  Tbar=(Tb+Th)/2
4055  Dqsdt=.622*Qs*(2500/(.287*Tbar*Tbar))! Thr IS THETA
         AT THE CLOUD TOP
4060  Beta=(1+Th*(1+Epsilon)*Dqsdt)/(1+2500*Dqsdt)! L&L/Cp<-
         --2500     Cp=1
4065  D2=Beta*Dte-Tbar*Dqw       ! IF NEGATIVE, THEN CLOUD
         TOP INSTABILITY
4070  Dthl=Dth-(Thr-Th)
4075  D1=Dthl*(1+Epsilon*Qs)+Epsilon*Tbar*Dqw ! QV=QS IN A
         CLOUD
4080  See=MIN(1,MAX(0,Zlcl/Zi))    ! TRAP SEE BETWEEN 0 AND 1
4085  DEF FNHvi(A)=MAX(0,A)        ! HEAVISIDE FUNCTION
4090  Rb=Emiss*Sigma*(Tb^4-Tsky^4)! SHOULD BE POSITIVE
         UNDER MOST
4095  Rc=Emiss*Sigma*(Tsfc^4-Tc^4)! NORMAL CONDITIONS
```

```
4100  IF See=1 THEN Rb=Rc=0
4105  Wth=-Ust*Tst
4110  Wq=-Ust*Qst/1000  ! USING GRAMS PER GRAM
4115  Wthv=-Ust*Tstv
4120  Wthe=Wth+2500*Wq
4125  M1=(2-See)*See*FNHvi(Wthv)+(1-See)*(1-See)*FNHvi(Beta*
         Wthe-Th*Wq)
4130  N1=(2-See)*See*FNHvi(-Wthv)+(1-See)*(1-See)*FNHvi(-
         Beta*Wthe+Th*Wq)
4135 M2=See*See*(FNHvi(Rb)-Rc)+(1-See)*(1-See)*Beta*Rc+(1-
         See*See)*Beta*FNHvi(Rb)
4140  N2=See*See*FNHvi(-Rb)+(1-See*See)*Beta*FNHvi(-Rb)
4145  M3=(1-See*See)*FNHvi(-D2)
4150  N3=See*See*D1+(1-See*See)*FNHvi(D2)
4155  We2=(.2*(M1+M2)-(N1+N2))/(N3-.2*M3)  !A=.2   RATIO OF
         ENTRAINMENT ENERGY
4160  IF We2>0 THEN GOTO 4185                 ! TO TOTAL TKE
4165  IF (D2<0) AND (See<1) THEN We2=.005*(1-See*See)!CLOUD
         TOP INSTABILITY
4170  IF (D2<0) AND (See=1) AND (Wthv>0) THEN We2=
         .001!ENCROACHMENT
4175  IF (D2<0) AND (See=1) AND (Wthv<0) THEN We2=.0005
         !STABLE ENCROACHMENT
4180  IF We2<0 THEN We2=.0001
4185  Delr2=Rb-Rc   ! DONE HERE CALCULATED FROM THE WATER
         CONTENT, TEMP OF SKY, CLOUD EMISSIVITY (THICKNESS
         OF CLOUD)          TOP MINUS BOTTOM
4190  SUBEND!


4195 SUB Parcel0(The,Q10,Z,Rh,Th,Qv,Ql,Zs)
4200 Gam=.0098
4205 Gamdew=.00804
4210 Lcp=2.430
4215 Qq=Qt=Q10
4220 Zz=0
4225 GOSUB Td_find
4230 Td10=Td
4235 Zz=Z
4240 Thr=The-Lcp*Qt
4245 GOTO 4345
4250 Theth:Th=Thez-Lcp*10
4255 Cycle:Tdo=Th-Gam*Z
4260 T=Tx=Tdo
4265 Zz=0
4270 GOSUB Qvcal
4275 Qv=Qvb
4280 GOSUB Dqdtcal
4285 Dthe=(Thez-(Th+273.16)*(1+Lcp*Qv/(T+273.16))+273.16)/(
        1+Lcp*Qv/(T+273.16)+(Th+273.16)/(T+273.16)*Lcp*Dqdt)
4290 IF ABS(Dthe)<.0001 THEN RETURN
```

```
4295 Th=Th+Dtne
4300 GOTO Cycle
4305 Dqdtcal:Tx=Tdo+.001
4310   GOSUB Qvcal
4315   Dqdt=(Qvb-Qv)/.001
4320   RETURN
4325 Qvcal: Qvb=5.3542*EXP(-5399.286*(1/(Tx+273.16)-3.5905E-
       3))
4330     Sig=EXP(-1.1384E-4*Zz)
4335   Qvb=Qvb/Sig
4340     RETURN
4345   Zs=(Thr-Td10)/Gamdew
4350   IF Zs<0 THEN Zs=0
4355   IF Z>=Zs THEN GOTO 4400
4360   Th=Thr
4365   Tx=Th-Gam*Z
4370   Zz=Z
4375   GOSUB Qvcal
4380   Rn=Qt/Qvb*100
4385   Qq=Qv=Qt
4390   GOSUB Td_find
4395   GOTO 4420
4400   Thez=The
4405   GOSUB Theth
4410   Rh=100
4415   Td=Th-Gam*Z
4420   Ql=Qt-Qv
4425     SUBEXIT
4430 Td_find:    Sig=EXP(-1.1384E-4*Zz)
4435   Qx=Qq*Sig
4440     Td=5399.286/(21.064-LOG(Qx))-273.16
4445    RETURN
4450    SUBEND!


4455    SUB Shrtwv(Theta,Qlbm,Zc,Zb,Qt,Dtemp)! ADDED BY
           CHRIS FAIRALL  9FEB81
4460  IF (Zc>Zb) OR (Theta=PI/2) THEN Dtemp=0
4465  IF (Zc>=Zb) OR (Theta=PI/2) THEN SUBEXIT
4470  Qlbm=MAX(.00005,Qlbm)
4475  Qq=Qlbm/2
4480  DIM Xnd(4),Dr(4)
4485  Cldthk=Zb-Zc
4490  Delz=Cldthk
4495  Dr(1.0)=2.5
4500  Dr(2)=5
4505  Dr(3)=10
4510  Dr(4)=20
4515  Sh=(Qt-Qq/Cldthk*Delz/2)*1.19  !WATER VAPOR
4520  Qq=Qq*1.19  !LIQUID WATER
4525  Rm=(4774.648*Qq)^.333
```

```
4530  FOR I=1.0 TO 4  ! XND IS THE XLOUD DROPLET SPECT
4535    Xnd(I)=.829963*EXP(-LOG(Dr(I)/Rm)*LOG(Dr(I)/Rm)*
           4.4164)*1E8
4540  NEXT I
4545  CALL Kannrad(Cldthk,Sh,Xnd(*),Theta,0,Fheat,Ftop,
          Fbotdir,Fbotdif)
4550  ! Fbotdir  DOWNWARD DIRECT RAD AT CLOUD BOTTOM
4555  ! Fbotdif  DOWNWARD DIFFUSE RAD AT CLOUD BOTTOM
4560  ! Ftop     DOWNWARD DIRECT RAD AT CLOUDTOP
4565  ! Theta   ZENITH ANGLE
4570  Dtemp=Delz*Fheat/Zb/60
4575  SUBEND
4580  SUB Int779(Nxy,X,Xarray(*),Yarray(*),Y,Slope,Ix)
4585  OPTION BASE 1
4590  Ix=MIN(MAX(1,Ix),Nxy-1)
4595  IF Xarray(Ix)<X THEN 4615
4600  IF Ix<=1 THEN 5020
4605  Ix=Ix-1
4610  GOTO 4595
4615  IF X<=Xarray(Ix+1) THEN 4635
4620  IF Ix+1>=Nxy THEN 5020
4625  Ix=Ix+1
4630  GOTO 4595
4635  Slope=(Yarray(Ix+1)-Yarray(Ix))/(Xarray(Ix+1)-Xarray(
          Ix))
4640  Y=Slope*(X-Xarray(Ix))+Yarray(Ix)
4645  GOTO 4655
4650  Ix=-999
4655  SUBEND
4660  ! SUB A52 - INITIALIZE XKV ARRAY
4665  SUB A52(Xkv(*),U)
4670 ! DISP "A52"
4675  ! U IS PATH IN G/CM^2
4680  OPTION BASE 1
4685  MAT Xkv=ZER
4690  Xkv(6)=.05/U^.39!.022
4695  Xkv(7)=.09/U^.39!.094
4700  Xkv(8)=.26/U^.39!.169
4705  Xkv(9)=.28/U^.26!.145
4710  Xkv(10)=.36/U^.26!.211
4715  Xkv(11)=.66/U^.53!.591
4720  Xkv(12)=.97/U^.53!.943
4725  Xkv(13)=1.06/U^.53!.943
4730  Xkv(14)=.39/U^.68!.76
4735  Xkv(15)=.31/U^.68!.685
4740  SUBEND
4745  ! SUB A20 - COMPUTE NEEDED ELEMENTS FOR AUGMENTE
          MATRIX A
4750  SUB A20(A(*),T,Al,Be,P,Xk,Fi(*),Qext(*),Dr(*),D,Sa(*),
          Af(*),Sh,Xkv(*),Xnd(*),Ag,Iw,Xmu,Tau(*))
4755  OPTION BASE 1
```

```
4760 ! DISP "A20"
4765  CALL A28(G,T,Om,Dr(*),Xnd(*),Qext(*),D,Sa(*),Af(*),Sh,
         Xkv(*),Iw,Tau(*))
4770  Fo=Fi(Iw)
4775  Fq=G*G
4780  G=G/(1+G)
4785  T=(1-Om*Fq)*T
4790  Om=(1-Fq)*Om/(1-Om*Fq)
4795  D1=1-Om
4800  D2=1-Om*G
4805  Xk=(3*D1*D2)^.5
4810  P=(3*D1/D2)^.5
4815  D3=1-Xk*Xk*Xmu*Xmu
4820  A1=3*Om*(Fo/PI)*Xmu*Xmu*(1+G*D1)/(4*D3)
4825  Be=3*Om*(Fo/PI)*Xmu*(1+3*G*D1*Xmu*Xmu)/(4*D3)
4830  A(1,1)=1+2*P/3
4835  A(1,2)=1-2*P/3
4840  A(1,3)=A1+2*Be/3
4845  A(2,1)=(1-Ag-2*(1+Ag)*P/3)*EXP(-Xk*T)
4850  A(2,2)=(1-Ag+2*(1+Ag)*P/3)*EXP(Xk*T)
4855  A(2,3)=((1-Ag)*A1-2*(1+Ag)*Be/3+Ag*Xmu*(Fo/PI))*EXP(-
         T/Xmu)
4860  SUBEND
4865  ! SUB A30 - COMPUTE NET FLUXES - FTOP AND ARRAY FL
4870  SUB A30(Fl,Fbotdir,Fbotdif,Ftop,Ftopd,X(*),Xk,Fi(*),T,
         A1,Be,P,Iw,Xmu)
4875  OPTION BASE 1
4880 ! DISP "A30"
4885  T0=0
4890  I0=X(1)*EXP(-Xk*T0)+X(2)*EXP(Xk*T0)-A1*EXP(-T0/Xmu)
4895  I1=P*(X(1)*EXP(-Xk*T0)-X(2)*EXP(Xk*T0))-Be*EXP(-T0/
         Xmu)
4900  Fd=Fi(Iw)*Xmu    !DOWNWARD COMP AT CLOUD TOP IW BAND,
         PERPIND TO HORIZONTAL
4905  Ftop=Ftop-PI*(I0-2/3*I1)+Fd  !NET (D-U) AT CLOUD TOP,
         TOTAL
4910  Ftopd=Ftopd+Fd  !TOTAL DOWNWARD COMP
4915  I0=X(1)*EXP(-Xk*T)+X(2)*EXP(Xk*T)-A1*EXP(-T/Xmu)
4920  I1=P*(X(1)*EXP(-Xk*T)-X(2)*EXP(Xk*T))-Be*EXP(-T/Xmu)
4925  Fl=Fl+4/3*PI*I1  !NET AT LEVEL
4930  Fl=Fl+Fd*EXP(-T/Xmu)  !TOTAL NET (DIF+DIRECT) LEVEL I
4935  Fbotdif=Fbotdif+PI*(I0+2/3*I1)
4940  Fbotdir=Fbotdir+Fd*EXP(-T/Xmu)
4945  SUBEND
4950  ! SUB A28 - AVERAGE SA,AF ARRAYS AND STORE IN OM,G;
         COMPUTE T
4955  SUB A28(G,T,Om,Dr(*),Xnd(*),Qext(*),D,Sa(*),Af(*),Sh,
         Xkv(*),Iw,Tau(*))
4960 ! DISP "A28"
4965  OPTION BASE 1
4970  Om=G=Ts=0
```

```
4975  FOR J=1 TO 4
4980  Tau(J)=Qext(Iw,J)*PI*(Dr(J)*1E-6)^2*Xnd(J)*D
4985  Ts=Ts+Tau(J)
4990  NEXT J
4995  T=Ts
5000  FOR J=1 TO 4
5005  Om=Om+Sa(Iw,J)*(Tau(J)/Ts)
5010  G=G+Af(Iw,J)*Tau(J)/Ts
5015  NEXT J
5020  Vp=Sn*D*1E-4
5025  Om=Om/(1+Xkv(Iw)*Vp/T)
5030  SUBEND
5035  ! SUB A100 - COMPUTE QEXT,SA,AF ARRAYS - ROUTINE FROM
        A. GOROCH
5040  SUB A100(Qext(*),Sa(*),Af(*),Dr(*))
5045 ! DISP "A100"
5050  OPTION BASE 1
5055  DIM X19(15),Xn9(15),Xk9(15)
5060  DATA 0.25,0.35,0.45,0.55,0.65,0.75,0.85,0.95,1.05,1.15
5065  DATA 1.25,1.35,1.45,1.55,1.65
5070  DATA 1.362,1.345,1.335,1.333,1.332,1.3,1.329,1.327,
        1.326,1.325
5075  DATA 1.323,1.321,1.320,1.318,1.316
5080  DATA 2.5,5,10,20
5085  RESTORE 5060
5090  MAT READ X19,Xn9,Dr
5095  MAT Xk9=ZER
5100  REM EVALUATE EXTINCTION USING DEIRMENDJIAN
        APPROXIMATION
5105  FOR Ix9=6 TO 15
5110  X10=X19(Ix9)
5115  Xn0=Xn9(Ix9)
5120  FOR I=1 TO 4
5125  R2=Dr(I)
5130  R0=4*PI*R2/X10*(Xn0-1)
5135  Qsca=Qext(Ix9,I)=2
5140  Sa(Ix9,I)=Qsca/Qext(Ix9,I)
5145  IF Sa(Ix9,I)=1 THEN Sa(Ix9,I)=.9999999999
5150  Af(Ix9,I)=1.8*(.5+EXP(-4*R0)/R0+(EXP(-4*R0)-1)/(4*R0)^
        2)
5155  NEXT I
5160  NEXT Ix9
5165 ! DISP ""
5170  SUBEND
5175  SUB Kahnrad(Cldthk,Sh,Xnd(*),Theta,Itest,Fheat,Iinc0,
        Fbotdir,Fbotdif)
5180 ! DISP "KAHNRAD"
5185  OPTION BASE 1
5190  DIM A(2,3),R(3),X(2)
5195  DIM Qext(15,4),Sa(15,4),Af(15,4)
5200  DIM Dr(4),Tau(4),Alam(15)
```

```
5205  DIM Fi(15),Xkv(15)
5210  ! I. INITIALIZATION
5215  DATA .0165,.1580,.2839,.2765,.2318,.1822,.1435,.1149,
          .0948,.0792
5220  DATA .0643,.0518,.0424,.0348,.0288
5225  DATA .2,.5355,.803,.909,.953,.960,.960,.920,.933,.940,
          .850,.780,.770,.880,.910
5230  RESTORE 5215
5235  MAT READ Fi,Alam
5240  U=MAX(.05,Sh*Cldtnk*1E-4)
5245  Fbotdir=Fbotdif=Ftop=Ftopd=Ftopdir=0
5250  IF Itest=1 THEN Theta=PI/4
5255  Xmu=COS(Theta)
5260  IF Xmu=0 THEN 5285
5265  Secmu=1/Xmu
5270  FOR I=1 TO 15
5275  Fi(I)=Fi(I)*Alam(I)^Secmu
5280  NEXT I
5285  Ag=.1   ! SURFACE ALBEDO
5290  IF Xmu>.7 THEN Ag=.05
5295  Delz=Cldthk
5300  F1=0
5305  D=Delz
5310  CALL A100(Qext(*),Sa(*),Af(*),Dr(*))
5315  CALL A52(Xkv(*),U)
5320  ! II. SOLUTION OF EQUATIONS
5325  FOR Iw=6 TO 15
5330  CALL A20(A(*),T,A1,Be,P,Xk,Fi(*),Qext(*),Dr(*),D,Sa(*)
          ,Af(*),Sh,Xkv(*),Xnd(*),Ag,Iw,Xmu,Tau(*))
5335  ! PERFORM GAUSS ELIMINATION ON MATRIX A
5340  FOR L=1 TO 2
5345  I1=L
5350  Dd=A(L,L)
5355  IF ABS(Dd)>.000001 THEN 5405
5360  I1=I1+1
5365  IF I1>2 THEN 5545
5370  FOR Iwi=1 TO 3
5375  R(Iwi)=A(L,Iwi)
5380  A(L,Iwi)=A(I1,Iwi)
5385  A(I1,Iwi)=R(Iwi)
5390  NEXT Iwi
5395  Dd=A(L,L)
5400  GOTO 5355
5405  FOR Ibi=1 TO 3
5410  A(L,Ibi)=A(L,Ibi)/Dd
5415  NEXT Ibi
5420  FOR J=L+1 TO 2
5425  Dd=A(J,L)
5430  FOR K=1 TO 3
5435  A(J,K)=A(J,K)-Dd*A(L,K)
5440  NEXT K
```

```
5445  NEXT J
5450  NEXT L
5455  FOR K=2 TO 2 STEP -1
5460  FOR J=K-1 TO 1 STEP -1
5465  A(J,3)=A(J,3)-A(J,K)*A(K,3)
5470  A(J,K)=0
5475  NEXT J
5480  NEXT K
5485  FOR I=1 TO 2
5490  X(I)=A(I,3)
5495  NEXT I
5500  CALL A30(Fl,Fbotdir,Fbotdif,Ftop,Ftopd,X(*),Xk,Fi(*),
         T,Al,Be,P,Iw,Xmu)
5505  NEXT Iw
5510  ! III.  OUTPUT MODULE
5515  Fheat=(Ftop-Fl)/D*35.014
5520  Iinc0=Ftopd
5525  Ftop=Iinc0=Iinc0/1.7136
5530  Fbotdir=Fbotdir/1.7136
5535  Fbotdif=Fbotdif/1.7136
5540  SUBEND
5545  PRINT "INDETERMINATE"
5550  SUBEND
5555  SUB Sky2(Zi,Nsnd,Pot_temp(*),Zsnd(*),Spec_num(*),Tsky,
         Ftop)
5560  DATA 0,.00001,.0000215,.0000464,.0001,.000215,.000464,
         .001,.00215,.00464,.01,.0215,.0464,.1,.215,.464,1,
         2.15,4.64,10,21.5,46.4,-999
5565  DATA 0,1.86,2.58,4.11,5.72,7.81,11.4,14.6,18.3,23.6,
         27.7,31.9,37.4,41.7,46.2,52.9,59,66.6,78.8,88.1,
         95.1,98.8,-999
5570  DATA .0098,1.225,10094,4.61E-11,0,1,0
5575  OPTION BASE 1
5580   DIM Tu(23),Temis(23),Emit(2),Thrsnd(30),Qtsnd(30)
5585   RESTORE 5560
5590   MAT Qtsnd=Spec_num
5595   MAT Thrsnd=Pot_temp
5600   MAT READ Tu,Temis
5605   READ Gad,Rho0,Zscale,Sig,U,Ii,S
5610   Nemis=22
5615  ! THRSND() IS TH RADIOSND
5620  ! ZSND() IS ALTI IN M,RADSN
5625  ! NEMIS IS # OF EMISSIVITY POINTS IN TEMISS
5630  ! TU(23),U DATA
5635  ! TEMIS(23),EMISSIVITY DATA
5640  ! ITOP IS INDEX FOR ZSND=ZI, IE WHAT LEVEL IN RADSND
         IS AT INVERSION
5645  ! NSND IS NUMBER IS POINTS IN RADIOSOND
5650  ! ICLOUD IS INDEX OF UPPER LEVEL CLOUDS
5655  Icloud=Nsnd  !ASSUME NO UPPER LEVEL CLOUDS
5660    Nsnd=Nsnd-1
```

```
5665   IF Nsnd<=0 THEN SUBEXIT
5670  FOR Itop=1 TO Nsnd
5675    IF Zsnd(Itop)>Zi THEN GOTO 5685
5680    NEXT Itop
5685    Itop=Itop-1
5690  DISP "SKY2"
5695  Tts=Thrsnd(Itop)-Gad*Zsnd(Itop)
5700  Emit(Ii)=0
5705  FOR I=Itop+1 TO Nsnd-1
5710  Ii=3-Ii
5715  IF I>Icloud THEN GOTO 5785
5720  U=U+Qtsnd(I)*(.00005*(Zsnd(I+1)-Zsnd(I-1))*Rho0*EXP(-
         Zsnd(I)/Zscale))
5725  CALL Int779(Nemis,U,Tu(*),Temis(*),Emit(Ii),Es,Ie)
5730  Tt=Thrsnd(I)-Gad*Zsnd(I)
5735  S=S-Emit(Ii)*Sig*((Tt+273.16)^4-(Tts+273.16)^4)/100
5740  Tts=Tt
5745  NEXT I
5750  Tt=Thrsnd(Nsnd)-Gad*Zsnd(Nsnd)
5755  U=U+Qtsnd(Nsnd)*.0001*(Zsnd(Nsnd)-Zsnd(Nsnd-1))*Rho0*
         EXP(-Zsnd(Nsnd)/Zscale)
5760  CALL Int779(Nemis,U,Tu(*),Temis(*),Emit(Ii),Es,Ie)
5765  S=S+Sig*(Tt+273.16)^4*Emit(Ii)/100
5770  Icloud=Nsnd
5775  Ftop=0
5780  GOTO 5795
5785  Tt=Thrsnd(Icloud)-Gad*Zsnd(Icloud)
5790  Ftop=Sig*(Tt+273.16)^4
5795  Tsky=((Ftop*(1-Emit(Ii))+S)/Sig)^.25
5800  DISP ""
5805  SUBEND
5810  SUB Zenith(Time,Julday,Lat,Theta)
5815  RAD
5820     Hr=Time/3600 MOD 24-12
5825     Latr=Lat*.017453
5830     H=Julday*.017214
5835    Decl=.006918-.399912*COS(H)+.070257*SIN(H)-.006758*
           COS(2*H)+.000907*SIN(2*H)-.002697*COS(3*H)+
           .000148*SIN(3*H)
5840     Theta=ACS(SIN(Latr)*SIN(Decl)+COS(Latr)*COS(Decl)*
           COS(Hr*PI/12))
5845    IF Theta>PI/2 THEN Theta=PI/2
5850      SUBEND
```

APPENDIX E:

MAJOR PROGRAM VARIABLES IN PREDICTION CODE:

Alpha_t ... ratio of heat transfer to momentum transfer exchange coefficient for neutral conditions (Psi=0)

Aws ... subsidence rate value at initial inversion height[m/s]

Cdn ... neutral drag coefficient

Ctn_sqrt ... square root of the temperature structure function parameter

Ddqwdt ... rate of change of specific humidity within the layer [g/kg-s]

Ddtedt ... rate of change of equivalent potential temperature within the layer [K/s]

Delr ... radiation flux divergence at cloud top [km/s]

Deltim ... prediction time step [1800 sec]

Dhdt ... rate of change of the mixed layer height and is the sum of entrainment and subsidence effects [m/s]

Dqdzu ... lapse rate of specific humidity above the layer [g/kg-km]

Dqw ... jump in specific humidity at the inversion [g/kg]

Dqwdt ... rate of change of specific humidity jump [g/kg-s]

Dtdzu ... lapse rate of potential temperature above the layer [K/km]

Dte ... jump in equivalent potential temperature at the layer [K]

Dtedt ... rate of change of equivalent potential temperature

Dtedzu ... lapse rate of equivalent potential temperature above the layer [K/km]

Dth ... jump in potential temperature at the layer [K]

Kkk ... Von Karman constant (.35)

Lcp ... liquid water content

Mixq ... initial value of mixed layer specific humidity

Mixtemp ... initial value of mixed layer potential temperature

Nr11 ... beginning in half hour period [e.g. 1200=24]

Nrad ... 100 times the ratio of buoyancy in clouds

Press ... surface pressure, default to 1012 mb unless entered from IREPS [mb]

Psi1 ... stability correction to logarithmic surface layer wind profile. Determined from surface stability. (Businger et al, 1971)

Psi2 ... stability correction to logarithmic surface layer temperature and humidity profiles. determined from surface stability. (Businger et al, 1971)

Q10 ... Qp ... computed well-mixed specific humidity which is assigned to the 10 meter level [g/kg]

Qst ... surface layer specific humidity scaling parameter, -Wq/Ust,[g/kg]

Qw ... total (liquid + vapor) specific humidity [g/kg]

S ...surface layer stability (S=Z/L, L=Monin-Obunkov length)

T10 ... well-mixed potential temperature which is assigned

to the 10 meter level [K]

Te ... equivalent potential temperature

Th ... well-mixed potential temperature in degrees Kelvin

Tsfc ... surface temperature [K]

Tst ... surface layer temperature scaling parameter [K]

Tstv ... surface layer virtual potential temperature scaling parameter [K]

U10 ... well-mixed wind speed which is assigned to the 10 meter level [m/s]

Ust ... surface layer momentum scaling parameter [m/s]

Vdte ... advection above the layer

We ... entrainment rate [m/s]

Ws ... subsidence rate [m/s]

Wq ... surface flux of specific humidity [g/g]

Wst ... mixed layer convective scaling velocity [m/s]

Wto ... surface flux of temperature [K-m/s]

Wtv ... surface flux of vertical potential temperature (buoyancy flux) [K-m/s]

Zi ... height of the layer [m]

Zlcl ... lifting condensation level [m]

Zo ... surface roughness parameter for momentum [m]

Zot ... surface roughness parameter for temperature and humidity [m]

Zws ... initial height used for subsidence rate reference[m]

VARIABLE CROSS REFERENCE

MAIN PROGRAM

COMMON VARIABLES:

Air	115	1070	1850				
Change	115	1070					
Coml(*)	120						
Delta	115	1070	1850				
Envnam$(*)	125	945	1005	1055			
Envsq(*)	120	930	965	995	1055	1060	
Evap$	95	1060					
Height$	95						
Height(*)	110	1065	1080	1090	1095	1455	1465
		1480	1620	1630	1865		
Htzero	115	1070					
Loc$	95	440	490	530	1060	1335	1845
		1940	2630	2900			
Losnam$(*)	125						
Lossq(*)	120	930					
Munits(*)	110	1065	1865				
Name$	95	1060					
Nmax	115	1070	1075	1080	1090	1095	1455
		1460	1465	1480	1620	1625	1630
		1865	1955				
Nunits(*)	110	1065					
Presur(*)	105	1065	1080	1865			
Przero	115	1070	1110	1850			
Recenv	115						
Relhm	115	1070	1850				
Relhum(*)	105	1065	1085	1865			
Sea	115	445	840	845	850	1070	1850
		2370					
Sysnam$(*)	125						
Syssq(*)	120	930					
Temper(*)	105	1065	1085	1090	1865		
Time$	95	440	490	530	1060	1335	1845
		1945	2630	2900			
Type$	95	1060					
Wind	115	575	580	1070	1850		
Wmo$(*)	100	1060					
Wmoht$	100	1060					

VARIABLES:

Aa	265	285	290	295	300	
Alpha_t	190	2380	2430	2470	2490	
Aws	2130	2280	2285			
Cc	3000	3005	3010	3015		
Cdn	2350	2355	2375	2385	2430	2470

Ctn_sqrt	2380	2385	2430	2470			
D	1780	1785	1790				
Date$	220						
Ddqwdt	2235	2265					
Ddtedt	2235	2275					
Delr	2235						
Deltim	190	2245	2250	2260	2265	2275	2285
Dhdt	2235	2245					
Digit_top	1100	1460	1625	1860			
Dqdzu	1920	2115	2205	2220	2565		
Dqp	1915	2110	2120	2270			
Dqw	2120	2235	2265	2270	2310		
Dqwdt	2235	2250					
Dtdzu	1930	2115	2205	2565			
Dte	2110	2235	2275	2310			
Dtedt	2235	2260					
Dtedzu	2115	2205	2235				
Dth	1925	2110	2310				
Dummy	1035	1040	1045	1050			
Flag_data	360	1130	2525				
Flag_rev	310	365	1125				
Frame_date$	155	1945	2565				
Frame_loc$	155	1940	2565				
Ftop	1955						
G(*)	180	550	630	675	745	770	780
		1120	2025	2050	2060	2070	2215
		2240	2245	2255	2270	2305	2310
		2345	2565	2655	2660	2665	2670
		2805	2825	2855	2870	2940	2950
G1	2645	2650	2655	2660	2665	2670	2675
G2	2650	2670					
G3	2655	2670					
G4	2660	2670					
G5	2665	2670					
Hd$	430	470	1835	2585	2590	2595	2600
		2625	2690	2895	2905	3020	3030
		3040					
Hight$	1060						
I	940	945	950	960	990	995	1005
		1010	1015	1020	1075	1080	1085
		1090	1095	1100	1105	1860	1865
		1870	2040	2045	2050	2055	2060
		2080	2085	2810	2825	2855	2875
		2945	2950	2955			
Idayl	755	765	775				
Ier	910	915	920	925			
Inl1$	535	540	545	550	565	595	610
		625					
Inl2$	645	650	655	660	665	670	675
J	160	960	965	970	2020	2065	2070
		2075	2175	2185	2210	2215	2225

		2240	2245	2255	2270	2305	2310
		2325	2345	2850	2855	2865	
Julday	170	445	490	495	2230		
K	2795	2805	2825	2830	2845	2855	2870
		2885					
Kkk	190	2375	2380	2385	2430	2470	2490
		2495					
L	1235	1240	1250	1255	1270	1275	1280
		1285	1295	1300	1305	1310	1430
		1435	1440	1445	1460	1465	1470
		1625	1630	1635	2825	2830	2835
		2840					
L$	165	2630	2635				
Lat	175	445	500	505	2230		
Lcp	2095	2105	2110	2115	2205	2300	2305
		2310					
L1	1265	1275	1280	1290			
Mass$	75	910	920				
Mhr	1960	1980	2175	2565	2645		
Mixq	1650	1660	1665	1685	1725	1730	1910
		1915					
Mixtemp	1490	1515	1525	1540	1575	1580	1900
		1925					
Mmm	1530	1650	1675	1780			
Mult	2490	2500	2505				
Nd	2055	2060	2065				
Nrl	2035	2040	2055	2060	2070	2080	
Nrll	565	620	630	675	745	755	770
		780	1980	1990	2020	2025	2035
		2145	2150	2155	2175	2210	2215
		2565	2645	2735	2740	2745	2755
		2765	2775	2785	2805	2825	2830
		2850	2870	2915	2925	2935	2940
		2945	2965	2980	2990	3000	
Nrec	1020	1030	1045				
Numhr	1980	2085					
O2	2220	2235					
P	2815	2855	2860				
Pot_temp(*)	165	1090	1455	1465	1480	1865	1955
Press	1110	1115	2565				
Psil	2405	2420	2430	2465	2470	2495	
Psi2	2410	2425	2430	2460	2470	2490	
Q$	570	585	590	635	680	695	720
		725	730	735			
Q10	2195	2235	2255				
Qdelta	2370	2385	2505				
Qp	1910	2105	2125	2195	2255	2370	
Qstar	2235	2505	2510				
Qw	2125	2250	2255	2305			
Rc$	355	390	400	405	410	415	
Rec	995	1000	1005	1050	1055	1060	

Run$	2170	2210	2215				
S	2385	2400	2420	2425	2430	2435	2440
		2450	2455	2470	2475	2480	
S1	2385	2435	2440	2475	2480		
So	2385	2390	2395	2430	2470		
Spec_hum(*)	165	1085	1620	1630	1645	1865	1955
Stick$(*)	155	190	1440				
T	2090	2095	2100	2295	2300		
T10	1900	2015	2190	2235			
Tday$	220	225	235	240	445	1335	1975
		2565	2630				
Tdelta	2365	2385	2500				
Te	2105	2260	2305				
Th	2015	2090	2105	2110	2115	2190	2205
		2305	2310	2365	2385	2510	
Theta	2230	2235					
Timesec	2225	2230					
Top_inv_q	1675	1685	1690	1710	1735	1915	1920
Top_inv_temp	1530	1540	1545	1565	1585	1925	1930
Top_q	1700	1710	1740	1920			
Top_q_alt	1700	1710	1740	1920			
Top_temp	1555	1565	1590	1930			
Top_temp_alt	1555	1565	1590	1930			
Tsfc	850	2235	2365				
Tsky	1955	2235					
Tstar	2235	2500	2510				
Tstv	2235	2510					
Tt	2100	2105	2110	2115	2205	2290	2295
		2305	2310				
U10	2345	2350	2355	2385	2495		
Ustar	2235	2495					
Vdt	1995	2005					
Vdte	2005	2275					
Vss	2555	2565	2570				
Win	455	460	465	640	665	670	675
		685	690	705	710	715	760
		765	770	775	780	785	795
		800					
Win1	750	765	770				
Wind_begin1	575	600	605	610	625	630	
WindIn(*)	155	460	520	565	630	670	675
		710	745	765	770	775	780
		1250					
Wn	455	560	685	705	760	800	1235
Ws	205	1935	2130	2235	2280		
Ws1	205	445	825	830	1415	1935	
Wtv	2235						
X1	2450	2465					
X2	2455	2460					
X5	2060	2070					
Z	190	2375	2380	2385	2490	2495	

Zi	1475	1490	1505	1525	1565	1580	1585
		1645	1665	1710	1715	1730	1735
		1905	1920	1930	1955	1990	2025
		2090	2100	2130	2135	2180	2185
		2235	2245	2280	2290	2295	
Zil	2180	2290					
Zi3	1475	1715	1905				
Zlcl	2235	2240					
Zo	2375	2495					
Zot	190	2380	2490				
Zsnd(*)	165	1095	1955				
Zws	2135	2285					

USER DEFINED FUNCTIONS:

FNQvalue	1085	2370	
FNRelhum	2665	2940	2950

SUB PROGRAMS:

Frame	2565
M2	2235
Sky2	1955
Zenith	2230

JUMP TARGETS:

155		80							
190		185							
220	Start:	875							
255	Option:								
260	Menu:	290	295	300	305	360	410	415	1030
			1040	2335	2525	2570			
310	Start_out:	300							
315	Start_out_ag	405							
350	Revchange:	300	400	420					
425	List_curr:	415							
490	Jullat:	320	415						
515	Enter_winds:	325	415						
530		525	540						
610		590							
645	One_wind:	655	660	805					
695	Print_wind:	650	740	810					
745		730							
795	Fixwind:	735	800						
815	Subsidence:	330	415						
840	Sea_temp:	335	415						
860	Assig_error:	905							
880	No_data:	860	915	925					
900	Ireps_data:	245							
960	All_out:	935							
975	All_full:	955							
980	Disp_data:	315	415	1045					
1020	Pick_data:	1000							

```
1110                    1080
1140 Plt_struct:         340    415   1790
1770                    1785
1885                    1835
1900 Run:                310    345
2045                    2050   2085
2175 Looper:
2340 Bulk:              2030   2320
2420                    2395   2445
2450                    2390   2485
2490 Stars:             2415   2435   2475
2520 Picture:            300   2550   2570   2580   2705   3040   3060
2585 Hard_output:        425   1830   2605   2615   2890
2610 Gval:              2570
2710 Mix_plot:          2570
3065 Bye:                300
3085                    3075
3095                    3085
3110 En:
```

SUB PROGRAM M2

COMMON VARIABLES:

VARIABLES:

```
 C1                     3130   3150
 Ddqwdt                 3115   3205
 Ddtedt                 3115   3200
 Delr                   3115   3180   3200   3210
 Dhdt                   3115   3195
 Dqdzu                  3115   3205
 Dqw                    3115   3180   3205   3215
 Dqwdt                  3115   3215
 Dte                    3115   3180   3200   3210
 Dtedt                  3115   3210
 Dtedzu                 3115   3200
 Dtemp                  3185   3200   3210
 Q10                    3115   3155   3160   3185
 Ql                     3160   3170   3185
 Qliq                   3170   3180
 Qs                     3165   3180
 Qst                    3115   3145   3180
 Qv                     3160   3165
 Rh                     3160   3165
 T10                    3115   3120   3155   3180
 Te                     3155   3160
 Thet                   3125   3150   3200   3210
 Theta                  3115   3185
 Thr                    3160   3130
 Tsfc                   3115   3180
```

Tsky	3115	3180					
Tst	3115	3135	3180				
Tstv	3115	3140	3180				
Tt	3120	3125	3130	3150			
Ust	3115	3135	3140	3145	3180		
We	3190	3195	3200	3205	3210	3215	
We2	3180	3190					
Wq	3145	3150	3205	3215			
Ws	3115	3195					
Wt	3135	3150					
Wte	3150	3200	3210				
Wtv	3115	3140					
Zi	3115	3120	3125	3160	3180	3185	3200
		3205	3210	3215			
Zlcl	3115	3160	3180	3185			

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

Parcel0	3160
Shrtwv	3185
We2	3180

JUMP TARGETS:

FNQvalue

COMMON VARIABLES:

VARIABLES:

Qvb	3230	3235
R	3225	3230
Tx	3225	3230

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM Frame::

COMMON VARIABLES:

VARIABLES:

A	3755	3760				
Bb	3370	3380	3385	3390	3400	
Bbb	3375	3385	3400			
Cc	3360	3365	3370	3375	3395	3405

Cv	3410	3415	3420	3425	3575	3580	3585
		3590					
D	3525	3530	3535	3540			
Dqdzu	3245	3640					
Dtdzu	3245	3645					
E	3660	3675					
Frame(*)	3245						
Frame_date$	3245	3310					
Frame_loc$	3245	3310					
G(*)	3245	3430	3445	3460	3470	3485	3495
		3625	3630	3640	3645	3755	
Hd$	3785	3790	3795				
Hrg	3615	3625	3630	3640	3645	3755	
I	3620	3640	3645	3655	3665	3675	3680
		3710	3715	3720			
Mhr	3245	3360	3440	3465	3490		
Nrll	3245	3270	3275	3280	3285	3305	3320
		3330	3350	3360	3415	3430	3440
		3460	3465	3485	3490	3615	
P	3655	3660	3675				
Pm	3610	3695	3705	3715	3735	3740	3750
		3930					
Pp(*)	3675	3705	3715	3725	3735	3740	3930
Pp1	3640	3660					
Pp2	3645	3665					
Pr	3605	3610	3615	3765			
Press	3245	3655					
Sbd	3565	3815	3940				
T	3665	3675					
Tday$	3245	3300					
V	3440	3445	3450	3465	3470	3475	3490
		3495	3500				
Zg(*)	3255	3595	3600	3625	3630	3640	3645
		3655	3665	3675	3705	3715	3735
		3740	3930				

USER DEFINED FUNCTIONS:

FNRelhum	3755

SUB PROGRAMS:

JUMP TARGETS:

3510 Profile:	
3840	3815
3915 Sfc_duct:	3725

FNRelhum

COMMON VARIABLES:

VARIABLES:

C	3975	3985
P	3980	3985
Q	3965	3985
Relhum	3985	3990
T	3965	3970
T1	3970	3975

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM Ne2

COMMON VARIABLES:

VARIABLES:

A	4085						
Beta	4060	4065	4125	4130	4135	4140	
D1	4075	4150					
D2	4065	4145	4150	4165	4170	4175	
Delr2	4000	4185					
Dqsdt	4055	4060					
Dqw	4000	4005	4065	4075			
Dte	4000	4005	4065				
Dth	4005	4070					
Dthl	4070	4075					
Emiss	4035	4090	4095				
Epsilon	4020	4060	4075				
M1	4125	4155					
M2	4135	4155					
M3	4145	4155					
N1	4130	4155					
N2	4140	4155					
N3	4150	4155					
Qliq	4000	4030					
Qs	4000	4055	4075				
Qst	4000	4110					
Rb	4090	4100	4135	4140	4185		
Rc	4095	4100	4135	4185			
See	4080	4100	4125	4130	4135	4140	4145
		4150	4165	4170	4175		
Sigma	4025	4090	4095				
Tb	4045	4050	4090				
Tbar	4050	4055	4065	4075			
Tc	4040	4095					
Th	4015	4040	4050	4060	4070	4125	4130
Thl	4000	4015					
Thr	4010	4045	4070				

```
 Thrl              4000   4010
 Tsfc              4000   4095
 Tsky              4000   4090
 Tst               4000   4105
 Tstv              4000   4115
 Ust               4000   4105   4110   4115
 We2               4000   4155   4160   4165   4170   4175   4180
 Wl                4030   4035
 Wq                4110   4120   4125   4130
 Wth               4105   4120
 Wthe              4120   4125   4130
 Wthv              4115   4125   4130   4170   4175
 Zi                4000   4035   4045   4080
 Zlcl              4000   4035   4040   4080

USER DEFINED FUNCTIONS:
 FNHvi             4085   4125   4130   4135   4140   4145   4150

SUB PROGRAMS:

JUMP TARGETS:
 4185              4160


SUB PROGRAM Parcel0

COMMON VARIABLES:

VARIABLES:
 Dqdt              4285   4315
 Dthe              4285   4290   4295
 Gam               4200   4255   4365   4415
 Gamdew            4205   4345
 Lcp               4210   4240   4250   4285
 Ql0               4195   4215
 Ql                4195   4420
 Qq                4215   4385   4435
 Qt                4215   4240   4380   4385   4420
 Qv                4195   4275   4285   4315   4385   4420
 Qvb               4275   4315   4325   4335   4380
 Qx                4435   4440
 Rh                4195   4380   4410
 Sig               4330   4335   4430   4435
 T                 4260   4285
 Td                4230   4415   4440
 Tdl0              4230   4345
 Tdo               4255   4260   4305
 Th                4195   4250   4255   4285   4295   4360   4365
                          4415
 The               4195   4240   4400
 Thez              4250   4285   4400
```

Thr	4240	4345	4360				
Tx	4260	4305	4325	4365			
Z	4195	4235	4255	4355	4365	4370	4415
Zs	4195	4345	4350	4355			
Zz	4220	4235	4265	4330	4370	4430	

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

4250 Theth:	4405		
4255 Cycle:	4300		
4305 Dqdtcal:	4280		
4325 Qvcal:	4270	4310	4375
4345	4245		
4400	4355		
4420	4395		
4430 Td_find:	4225	4390	

SUB PROGRAM Shrtwv

COMMON VARIABLES:

VARIABLES:

Cldthk	4485	4490	4515	4545		
Delz	4490	4515	4570			
Dr(*)	4480	4495	4500	4505	4510	4535
Dtemp	4455	4460	4570			
Fbotdif	4545					
Fbotdir	4545					
Fheat	4545	4570				
Ftop	4545					
I	4530	4535	4540			
Qlbm	4455	4470	4475			
Qq	4475	4515	4520	4525		
Qt	4455	4515				
Rm	4525	4535				
Sh	4515	4545				
Theta	4455	4460	4465	4545		
Xnd(*)	4480	4535	4545			
Zb	4455	4460	4465	4485	4570	
Zc	4455	4460	4465	4485		

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

Kahnrad	4545

JUMP TARGETS:

SUB PROGRAM Int779

COMMON VARIABLES:

VARIABLES:

Ix	4580	4590	4595	4600	4605	4615	4620
		4625	4635	4640	4650		
Nxy	4580	4590	4620				
Slope	4580	4635	4640				
X	4580	4595	4615	4640			
Xarray(*)	4580	4595	4615	4635	4640		
Y	4580	4640					
Yarray(*)	4580	4635	4640				

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

4595	4610	4630
4615	4595	
4635	4615	
4655	4645	
5020	4600	4620

SUB PROGRAM A52

COMMON VARIABLES:

VARIABLES:

U	4665	4690	4695	4700	4705	4710	4715
		4720	4725	4730	4735		
Xkv(*)	4665	4685	4690	4695	4700	4705	4710
		4715	4720	4725	4730	4735	

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM A20

COMMON VARIABLES:

VARIABLES:

A(*)	4750	4830	4835	4840	4345	4850	4855

Af(*)	4750	4765					
Ag	4750	4845	4850	4855			
Al	4750	4820	4840	4855			
Be	4750	4825	4840	4855			
D	4750	4765					
D1	4795	4805	4810	4820	4825		
D2	4800	4805	4810				
D3	4815	4820	4825				
Dr(*)	4750	4765					
Fi(*)	4750	4770					
Fo	4770	4820	4825	4855			
Fq	4775	4785	4790				
G	4765	4775	4780	4800	4820	4825	
Iw	4750	4765	4770				
Om	4765	4785	4790	4795	4800	4820	4825
P	4750	4810	4830	4835	4845	4850	
Qext(*)	4750	4765					
Sa(*)	4750	4765					
Sh	4750	4765					
T	4750	4765	4785	4845	4850	4855	
Tau(*)	4750	4765					
Xk	4750	4805	4815	4845	4850		
Xkv(*)	4750	4765					
Xmu	4750	4815	4820	4825	4855		
Xnd(*)	4750	4765					

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

A28	4765

JUMP TARGETS:

SUB PROGRAM A30

COMMON VARIABLES:

VARIABLES:

Al	4870	4890	4915		
Be	4870	4895	4920		
Fbotdif	4870	4935			
Fbotdir	4870	4940			
Fd	4900	4905	4910	4930	4940
Fi(*)	4870	4900			
Fl	4870	4925	4930		
Ftop	4870	4905			
Ftopd	4870	4910			
I0	4890	4905	4915	4935	
I1	4895	4905	4920	4925	4935
Iw	4870	4900			

P	4870	4895	4920				
T	4870	4915	4920	4930	4940		
T0	4885	4890	4895				
X(*)	4870	4890	4895	4915	4920		
Xk	4870	4890	4895	4915	4920		
Xmu	4870	4890	4895	4900	4915	4920	4930
		4940					

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM A28

COMMON VARIABLES:

VARIABLES:

Af(*)	4955	5010					
D	4955	4980	5020				
Dr(*)	4955	4980					
G	4955	4970	5010				
Iw	4955	4980	5005	5010	5025		
J	4975	4980	4985	4990	5000	5005	5010
		5015					
Om	4955	4970	5005	5025			
Qext(*)	4955	4980					
Sa(*)	4955	5005					
Sh	4955	5020					
T	4955	4995	5025				
Tau(*)	4955	4980	4985	5005	5010		
Ts	4970	4985	4995	5005	5010		
Vp	5020	5025					
Xkv(*)	4955	5025					
Xnd(*)	4955	4980					

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM A100

COMMON VARIABLES:

VARIABLES:

Af(*)	5040	5150

Dr(*)	5040	5090	5125				
I	5120	5125	5135	5140	5145	5150	5155
Ix9	5105	5110	5115	5135	5140	5145	5150
		5160					
Qext(*)	5040	5135	5140				
Qsca	5135	5140					
R0	5130	5150					
R2	5125	5130					
Sa(*)	5040	5140	5145				
Xk9(*)	5055	5095					
X10	5110	5130					
X19(*)	5055	5090	5110				
Xn0	5115	5130					
Xn9(*)	5055	5090	5115				

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

5060	5085

SUB PROGRAM Kahnrad

COMMON VARIABLES:

VARIABLES:

A(*)	5190	5330	5350	5375	5380	5385	5395
		5410	5425	5435	5465	5470	5490
Af(*)	5195	5310	5330				
Ag	5285	5290	5330				
Al	5330	5500					
Alam(*)	5200	5235	5275				
Be	5330	5500					
Cldthk	5175	5240	5295				
D	5305	5330	5515				
Dd	5350	5355	5395	5410	5425	5435	
Delz	5295	5305					
Dr(*)	5200	5310	5330				
Fbotdif	5175	5245	5500	5535			
Fbotdir	5175	5245	5500	5530			
Fheat	5175	5515					
Fi(*)	5205	5235	5275	5330	5500		
Fl	5300	5500	5515				
Ftop	5245	5500	5515	5525			
Ftopd	5245	5500	5520				
Ftopdir	5245						
I	5270	5275	5280	5485	5490	5495	
Il	5345	5360	5365	5380	5385		
Ibi	5405	5410	5415				

Iinc0	5175	5520	5525				
Itest	5175	5250					
Iw	5325	5330	5500	5505			
Iwi	5370	5375	5380	5385	5390		
J	5420	5425	5435	5445	5460	5465	5470
		5475					
K	5430	5435	5440	5455	5460	5465	5470
		5480					
L	5340	5345	5350	5375	5380	5395	5410
		5420	5425	5435	5450		
P	5330	5500					
Qext(*)	5195	5310	5330				
R(*)	5190	5375	5385				
Sa(*)	5195	5310	5330				
Secmu	5265	5275					
Sh	5175	5240	5330				
T	5330	5500					
Tau(*)	5200	5330					
Theta	5175	5250	5255				
U	5240	5315					
X(*)	5190	5490	5500				
Xk	5330	5500					
Xkv(*)	5205	5315	5330				
Xmu	5255	5260	5265	5290	5330	5500	
Xnd(*)	5175	5330					

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

A100	5310
A20	5330
A30	5500
A52	5315

JUMP TARGETS:

5215	5230
5285	5260
5355	5400
5405	5355
5545	5365

SUB PROGRAM Sky2

COMMON VARIABLES:

VARIABLES:

Emit(*)	5580	5700	5725	5735	5760	5765	5795
Es	5725	5760					
Ftop	5555	5775	5790	5795			
Gad	5605	5695	5730	5750	5785		

```
 I                  5705  5715  5720  5730  5745
 Icloud             5655  5715  5770  5785
 Ie                 5725  5760
 Ii                 5605  5700  5710  5725  5735  5760  5765
                          5795
 Itop               5670  5675  5680  5685  5695  5705
 Nemis              5610  5725  5760
 Nsnd               5555  5655  5660  5665  5670  5705  5750
                          5755  5770
 Pot_temp(*)        5555  5595
 Qtsnd(*)           5580  5590  5720  5755
 Rho0               5605  5720  5755
 S                  5605  5735  5765  5795
 Sig                5605  5735  5765  5790  5795
 Spec_hum(*)        5555  5590
 Temis(*)           5580  5600  5725  5760
 Thrsnd(*)          5580  5595  5695  5730  5750  5785
 Tsky               5555  5795
 Tt                 5730  5735  5740  5750  5765  5785  5790
 Tts                5695  5735  5740
 Tu(*)              5580  5600  5725  5760
 U                  5605  5720  5725  5755  5760
 Zi                 5555  5675
 Zscale             5605  5720  5755
 Zsnd(*)            5555  5675  5695  5720  5730  5750  5755
                          5785

USER DEFINED FUNCTIONS:

SUB PROGRAMS:
 Int779             5725  5760

JUMP TARGETS:
 5560               5585
 5685               5675
 5785               5715
 5795               5780


SUB PROGRAM Zenith

COMMON VARIABLES:

VARIABLES:
 Decl               5835  5840
 H                  5830  5835
 Hr                 5820  5840
 Julday             5810  5830
 Lat                5810  5825
 Latr               5825  5840
 Theta              5810  5840  5845
```

Time 5810 5820

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

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